2 BACKGROUND AND CURRENT STATUS

This section includes overviews of the Lake Ozette watershed, the biology of sockeye salmon and the Lake Ozette sockeye ESU, as well as summaries of past and current land use in the watershed, current status of the sockeye population, and current hatchery management as it is relevant to sockeye recovery.

2.1 WATERSHED DESCRIPTION

Lake Ozette watershed is located along the northwest tip of the Olympic Peninsula in Washington State (Figure 2.1). Lake Ozette is situated on the coastal plain between the Pacific Ocean and the Olympic Mountains. The terrain of the Ozette watershed is slightly rolling to steep, with a gradual increase in elevation from zero feet at sea level (at the Ozette River mouth), to 34 feet at the lake's outlet, to just under 2,000 feet at the watershed's highest point in the upper Big River watershed. Most of the watershed ranges from 200 to 800 feet elevation. The geology of the Ozette watershed is an interesting mix of flat and gently sloping glacial and glacio-fluvial deposits situated between resistant knobs and small hills composed of Tertiary marine sedimentary rock units (mechanically weak silt- and sand-stones). Some glacial landforms extend for several square miles, while others occupy small valleys. Other portions of the watershed (e.g., upper Big River) are steep and rugged and are underlain by Eocene-age volcanic flows and breccias. The climate of the northwest Olympic Peninsula can be characterized as temperate coastal-marine, with mild winters and cool summers. Annual precipitation at the Quillayute State Airport from 1967 to 2005 averaged 102.6 inches. The bulk of this precipitation fell as rain between October and April.

Lake Ozette is approximately 8 miles (12.9 km) long from north to south and 2 miles (3.2 km) wide. The lake is irregularly shaped and contains several bays (North End, Deer, Umbrella, Swan, Ericson's, Boat, Allen's, and South End bays), distinct points (Deer, Eagle, Shafer's, Rocky, Cemetery, and Birkestol points) and three islands (Garden, Tivoli, and Baby Island). With a surface area of 11.8 mi^2 (30.6 km^2; 7,550 acres; 3,056 ha), Lake Ozette is the third largest natural lake in Washington State. The lake has a drainage basin area of 77 mi^2 (199.4 km^2), an average depth of approximately 130 feet (40 m), and a maximum depth of 320 feet (98 m) (Dlugokenski et al. 1981).

The average water surface elevation of the lake is 34 feet above mean sea level (msl) (10.4 m; National Geodetic Vertical Datum of 1929 [NGVD 1929]). In recent years (1982-2005), extreme low and high water surface elevations of the lake have ranged from 30.8 feet (9.4m) to 41.5 feet (12.6 m) above msl. Shoreline vegetation, substrate, and topography vary widely around the lake, with additional variations according to time of year and lake level.

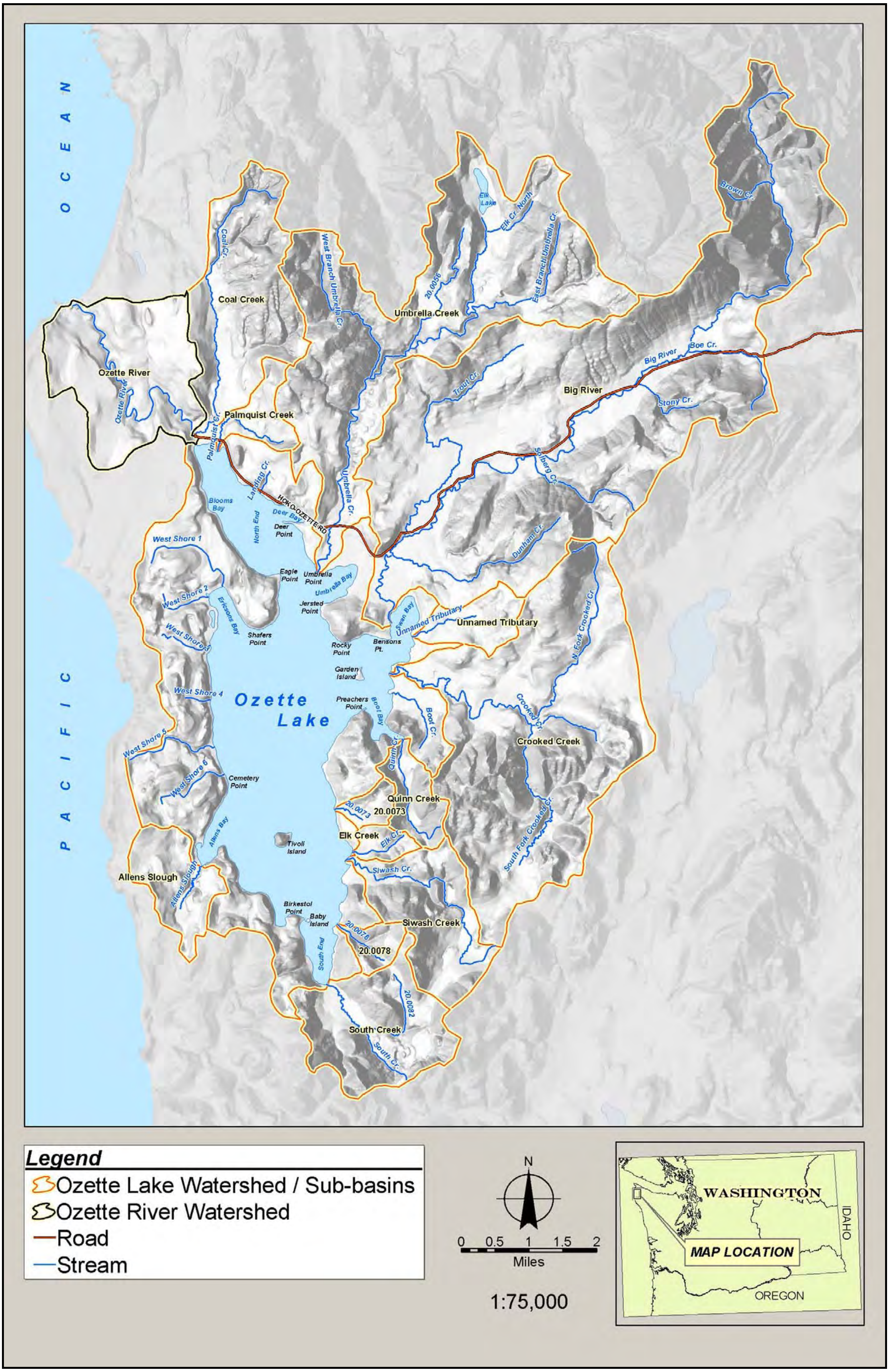

Figure 2.1. Lake Ozette watershed overview map.

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The Ozette River drains the lake from the North End; there are no other outlet streams draining the lake. The river travels approximately 5.3 miles (8.5 km) along a sinuous course to the Pacific Ocean. The total drainage area of the Ozette watershed at the confluence with the Pacific Ocean is 88.4 mi^2 (229 km^2). Coal Creek, which enters just downstream from the lake's outlet, is the largest tributary to the Ozette River. Several significant tributaries drain into Lake Ozette: Big River, Umbrella Creek, Crooked Creek, Siwash Creek, and South Creek (Table 2.1). Several smaller streams also feed the lake: Palmquist, Quinn, and Elk Creeks, as well as several other unnamed streams.

Wind and hydro-geomorphic events (e.g., floods and landslides) are considered the primary natural disturbance agents in coastal temperate rain forests, including the Ozette watershed (Alaback 1996). Strong winter storms are common on the Pacific coast, frequently causing windthrow and toppling shallow-rooted trees (ibid.). In addition, large magnitude (~magnitude 9) great earthquakes have been shown to recur at a 400-600 year frequency along this region of the Pacific Coast (Atwater and Hemphill-Haley 1997).

Table 2.1. Lake Ozette and tributary drainage basin areas.

Watershed/Subbasin	**Watershed/Subbasin Description**	**Basin Area (sq. mi.)**	**Basin Area (sq. km.)**
Big River	Entire Big River Watershed	22.8	59
Crooked Creek	Entire Crooked Creek Watershed	12.2	31.6
Umbrella Creek	Entire Umbrella Creek Watershed	10.6	27.6
South Creek	Entire South Creek Watershed	3.3	8.4
Siwash Creek	Entire Siwash Creek Watershed	2.9	7.4
Palmquist Creek	Entire Palmquist Creek Watershed	1.1	2.8
Lake Ozette Tributary	Unnamed Trib. between Crooked and Dunham Creeks	0.9	2.3
Quinn Creek	Entire Quinn Creek Watershed	0.9	2.3
Lake Ozette Tributary	Unnamed Tributary between Crooked and Quinn	0.7	1.7
Lake Ozette Tributary	Unnamed Tributary between Siwash and South Creeks	0.5	1.2
Unnamed Tributary 20.0073	Entire 20.0073 Watershed	0.4	0.9
Elk Creek	Entire Elk Creek Watershed	0.3	0.8
Lake Ozette Watershed	**Entire Lake Ozette Watershed**	**77**	**199**
Coal Creek	Entire Coal Creek Watershed	4.6	11.8
Ozette River at Pacific Ocean	**Entire Lake Ozette and Ozette River Watershed**	**88.4**	**229**

The Lake Ozette watershed is predominantly forested. Lake Ozette and Elk Lake are the largest unforested areas within the watershed. Other unforested areas also occur where bogs and open-water wetlands naturally exist. The forest contained within the Ozette watershed can be characterized as a coastal temperate rainforest ecosystem. Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*), are the dominant conifer species, followed by western red cedar (*Calocedrus decurrens*) pacific silver fir (*Abies amabilis*), Douglas fir (*Psuedotsuga mensiezii*), and western yew (*Taxus brevifolia*). Red alder (*Alnus rubra*) is the most prevalent deciduous tree, and is common along streams and disturbed sites. Vine maple (*Acer circinatum*) and bigleaf maple (*Acer macrophylla*) are also common in riparian areas, wetlands, and meadows. Schoonmaker et al. (1997) define this section of the Pacific coastal temperate rain forest as seasonal temperate rain forest, as compared to warm temperate rainforest to the south and perhumid temperate rain forest and sub-polar temperate rain forest zones to the north. It has been classified as seasonal because less than 10 percent of the total rainfall occurs during summer months.

Understory vegetation in mature temperate rainforests is complex. In the Ozette watershed there are approximately 363 vascular plant species (Buckingham et al. 1995). Fungi and lichen are ubiquitous in areas of primary forest. They compose a significant fraction of the forest biomass and play an important role in nutrient cycling within the forest ecosystem. The lake and watershed contain a diverse assemblage of terrestrial and aquatic mammals, birds, and amphibians.

The Lake Ozette fish community includes a rich array of approximately 25 species of fishes presumed to be present. There are seven "species" of salmonids present in the lake system including: sockeye salmon (*Oncorhynchus nerka*), kokanee salmon (*Oncorhynchus nerka kennerlyi*), coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), Chinook salmon (*Oncorhynchus tshawytscha*), rainbow/steelhead trout (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*). Approximately 18 non-salmonid fish species are also thought or known to be present within the Lake Ozette watershed, including the following: speckled dace (*Rhinichthys osculus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), reticulate sculpin (*Cottus perplexus*), riffle sculpin (*Cottus gulosus*), torrent sculpin (*Cottus rhotheus*), brook lamprey (*Lampetra richardsoni*), pacific lamprey (*Lampetra tridentata*), three-spine stickleback (*Gasterosteus aculeatus*), Olympic mudminnow (Novumbra hubbsi), peamouth (Mylocheilus caurinus), Tui chub (*Gila bicolor*), northern pikeminnow (*Ptychocheilus oregonensis*), redside shiner (*Richardsonius balteatus*), American shad (*Alosa sapidissma*), yellow perch (*Perca flavenscens*), largemouth bass (*Micropterus salmoides*), and brown bullhead (*Ictalurus nebulosus*) (MFM 2000; Gustafson 1997; Mongillo and Hallock 1997; Jacobs et al. 1996; MFM unpublished fish captures). Several other species of fish use the estuarine portion of the lower Ozette River and likely include sturgeon (*Acipenser spp.*), marine cottids, marine flatfish, and surf smelt (*Hypomesus pretiosus*).

2.2 SOCKEYE SALMON (General Overview)

Most of the time, salmon return to spawn in the streams or lakes where they were born. However, they occasionally "stray" and choose to mate where conditions are right, perhaps in an adjacent stream or lake. The result is that salmon populations that are geographically widespread may have some amount of genetic similarity. They are linked because of straying, and differentiated because of long-term adaptation to different environments.

All Pacific salmon belong to the family *Salmonidae* and the genus *Oncorhynchus*, while sockeye belong to the species *Oncorhynchus nerka*. Lake Ozette sockeye are an "evolutionarily significant unit" (ESU) of *O. nerka*. ESUs are defined on the basis of geographic range as well as genetic, behavioral, and other traits. Other salmonid ESUs are, for example, Puget Sound Chinook salmon, Hood Canal chum salmon, and Upper Columbia steelhead.

Sockeye salmon are the second most abundant of the seven Pacific salmon species (Quinn 2005). They display more life history diversity than all other members of the *Oncorhynchus* genus (Burgner 1991). Sockeye salmon are generally anadromous, but distinct populations of non-anadromous *O. nerka* also exist; these fish are commonly referred to as kokanee (*O. nerka kennerlyi*) or silver trout (Wydoski and Whitney 2003).

The vast majority of sockeye populations spawn in or near lakes. Spawning can take place in lake tributaries, lake outlets, rivers between lakes, and on lake shorelines or beaches where suitable upwelling or intra-gravel flow is present. Spawn timing is often determined by water temperature. In spawning habitats with cooler water temperatures, sockeye typically spawn earlier (August) than in warmer habitats (November) (Burgner 1991). Sockeye fry spawned in lake tributaries typically exhibit a behavior of rapid downstream migration to the nursery lake after emergence, whereas lake/beach spawned sockeye rapidly migrate to open limnetic waters after emergence. Lake-rearing juveniles typically spend 1 to 3 years in their nursery lake before emigrating to the marine environment (Gustafson et al. 1997). Other life history variants include sea-type and river-type sockeye. Sea-type (also referred to as ocean-type) populations typically use large rivers and side channels or spring-fed tributary systems for spawning and emigrate to sea soon after emergence. River-type sockeye rear in rivers for one year before emigrating to sea. Quinn (2005) describes the differences between sea-type and river-type sockeye as a continuum of rearing patterns rather than as two discrete types.

Upon smoltification, sockeye emigrate to the ocean. Peak emigration to the ocean occurs in mid-April to early May in southern sockeye populations (<52ºN latitude) and as late as early July in northern populations (62ºN latitude) (Burgner 1991). Typically, river-type sockeye populations make little use of estuaries during their emigration to the marine environment (Quinn 2005). Estuarine habitats may be more extensively used by sea-type sockeye (Quinn 2005). Upon entering marine waters, sockeye may reside in the nearshore or coastal environment for several months but are typically distributed offshore by fall (Burgner 1991).

In the marine environment, Asiatic sockeye are restricted to the zone north of 42ºN latitude and North American sockeye stocks to the zone north of 46ºN latitude. Within these zones, sockeye salmon have a wide distribution. In North America, their range is south to the Sacramento River (California; historical) and as far north as Kotzebue Sound (Alaska). However, sockeye in commercially important numbers occur only from the Columbia River to the Kuskokwim River in the Bering Sea (Foerster 1968; Burgner 1991; Quinn 2005). The Fraser River and Bristol Bay watersheds are the two dominant sockeye producing systems in North America (Gustafson et al. 1997). Other significant sockeye producing systems include the Chignik, Karluk, Cooper, Skeena, Nass, and Somass Rivers. Within the Gulf of Alaska, southern North American stocks (B.C/Washington) tend to be farther south than Alaskan stocks (Burgner 1991). In the Western Pacific, sockeye can be found from the Kuril Islands (Japan) to Cape Chaplina (Russia). More than 90 percent of all Asiatic sockeye are produced on the Kamchatka Peninsula, in the Ozernaya and Kamchatka River systems (Burgner 1991; Gustafson et al. 1997).

The extant sockeye populations of Washington State represent the current southern extent of the species range. The NMFS Biological Review Team (BRT) examined genetic, life history, biogeographic, geologic, and environmental information to define salmon ESUs in Washington State. They identified six sockeye salmon ESUs: Okanogan, Wenatchee, Quinault, Ozette, Baker, and Pleasant. The BRT identified Big Bear Creek, a tributary to Lake Sammamish, as a provisional ESU, but uncertainty regarding the historical presence of sockeye salmon in the Lake Washington/Sammamish drainage hindered definitive ESU identification. Sockeye spawn in several small aggregations in Washington rivers in the absence of lake-rearing habitat, but information on these riverine-spawning aggregations was insufficient to determine ESU status. Lake Ozette sockeye are distinguished from other Washington sockeye ESUs based upon unique genetic characteristics, early river entry, the relatively large adult body size, and large average smolt size relative to other coastal Washington sockeye populations (Gustafson et al. 1997).

2.3 LAKE OZETTE SOCKEYE SALMON ESU

Historically, the Ozette watershed had thriving populations of several salmon species, including sockeye salmon. Lake Ozette sockeye were an important contributor to the fisheries of the Makah and Quileute Tribes, as well as an important subsistence species for early settlers in the watershed. Although the Makah Tribe’s annual harvest[1] of Lake Ozette sockeye reached an estimated high of more than 17,000 in 1949 (WDF 1955; Figure 2.2), the harvest declined sharply in the 1960s because of declining numbers of the fish. The Makah Tribe’s commercial sockeye fishery ceased in 1974 and all Makah Tribal ceremonial and subsistence fishing ended in 1982, in an effort to protect and increase the abundance of spawning sockeye. Despite the cessation of sockeye harvest, sockeye abundance has not rebounded.

In 1997, the National Marine Fisheries Service (NMFS) West Coast Sockeye Biological Review Team (BRT) concluded that if present conditions (those observed in the early and mid-1990s) continued into the future, Lake Ozette sockeye were likely to become in danger of extinction in the foreseeable future (Gustafson et al. 1997). In 1999, Lake Ozette sockeye salmon were listed as a threatened species under the Endangered Species Act (ESA) (64 FR 14528, March 25, 1999). The listing was primarily attributed to

[1] There is no documented harvest in the catch record for Lake Ozette sockeye salmon by non-treaty commercial and/or sport fisheries or Quileute Tribal fisheries.

concerns over abundance and effects of small population genetic and demographic variability.

The Lake Ozette sockeye salmon ESU is made up of only one population (Currens et al. 2006), which currently contains five distinct spawning aggregations that are also described in this plan as subpopulations. The subpopulations can be grouped according to whether they spawn in tributaries (Umbrella Creek, Big River, and Crooked Creek) or near lake beaches (Olsen's Beach and Allen's Beach). Current and historical known beach spawning sites are depicted in Figure 2.3. Certain limiting factors, habitat conditions, and life histories are common to all the subpopulations, while others vary between subpopulations but can be grouped based on spawning environment (i.e., tributary vs. beach) (Figure 2.4).

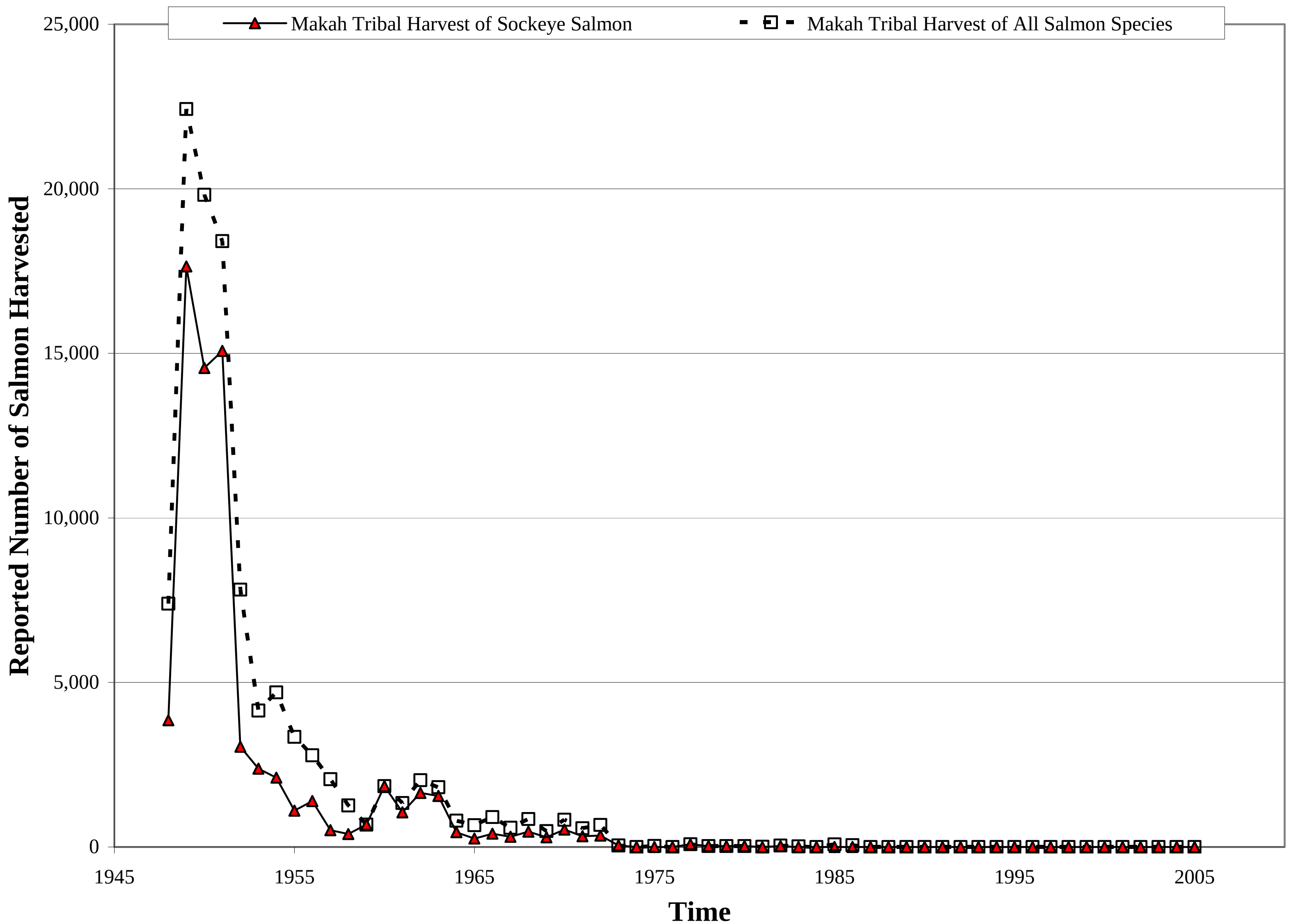

Figure 2.2. Reported Makah Tribal harvest of Lake Ozette sockeye and other Lake Ozette salmon species from 1948 to 2005. Note: No harvest record data exist for the period prior to 1948. (Source: WDF 1955; Jacobs et al. 1996; Haggerty et al. 2007)

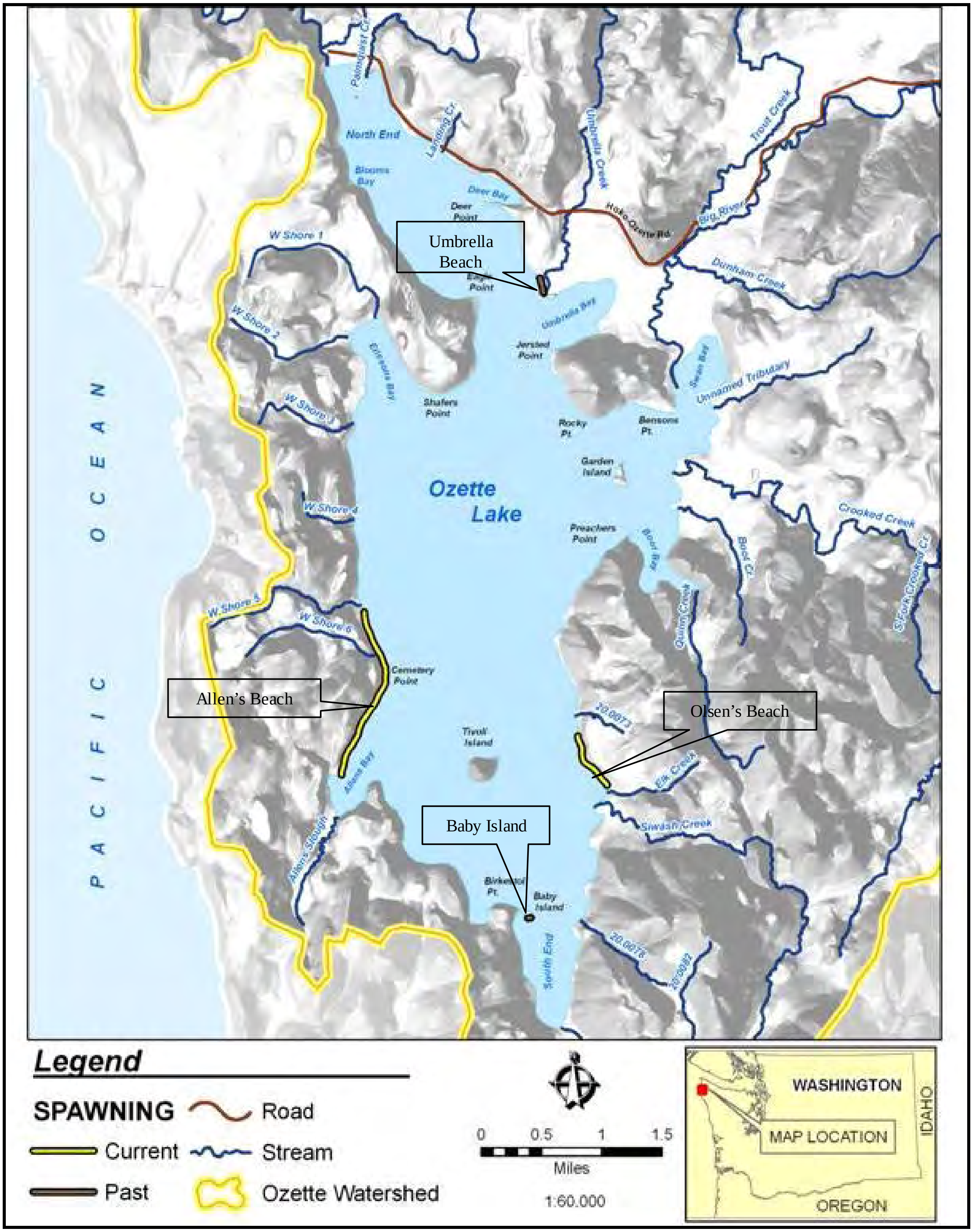

Figure 2.3. Known current and historical Lake Ozette sockeye beach spawning locations (modified from Haggerty et al. 2007).

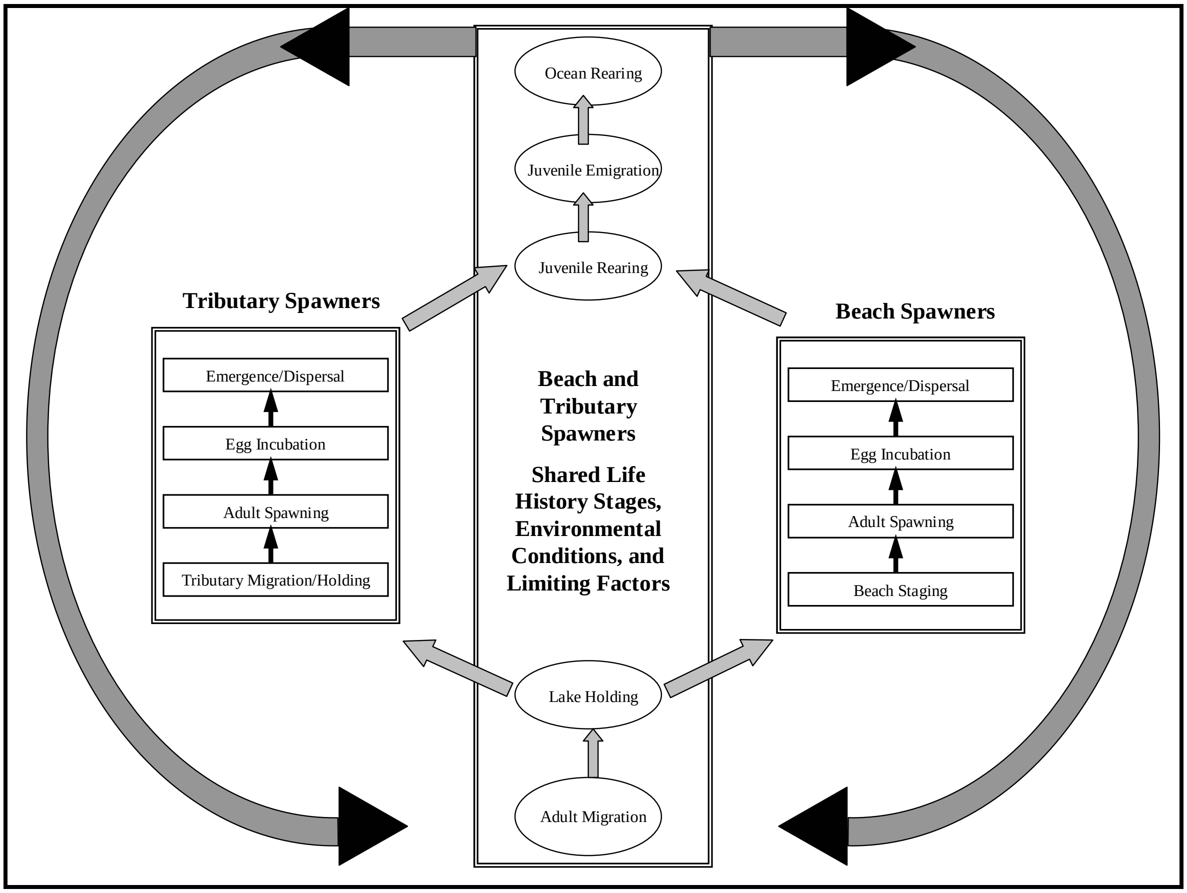

Figure 2.4. Conceptual diagram of Lake Ozette sockeye salmon life histories.

After the ocean rearing/migration phase, sockeye return to Lake Ozette from mid-April to mid-August, primarily as age-4 adults. Beach spawners are almost exclusively age 4 (~99 percent), whereas preliminary otolith age data from tributary spawners indicates that up to 9 percent of these returning adults are ages 3 and 5 (Haggerty et al. 2007). Sockeye hold for an extended period in Lake Ozette (2-10 months). Adult sockeye begin entering the lake in mid-April, and have been observed spawning on spawning beaches through late February. Peak spawning in tributaries takes place in November and December, while some spawning in January has also been observed. Egg incubation occurs from as early as October through as late as May, and fry emergence and dispersal in the lake occurs from February through May. Limited evidence indicates that beach fry move rapidly into offshore rearing areas and that tributary fry migrate to the lake soon after emergence and exclusively at night (Haggerty et al. 2007).

Almost all (~99 percent) juvenile sockeye rear in the lake for one summer and emigrate to sea during their second spring as age-1+ smolts. During the juvenile rearing phase sockeye salmon feed primarily on zooplankton. *Daphnia pulicaria* dominate the diet of juvenile sockeye salmon throughout the year. For detailed information on Lake Ozette sockeye salmon life histories, please refer to the Lake Ozette Sockeye Limiting Factors Analysis (LFA) (Haggerty et al. 2007). Figure 2.5 illustrates the seasonal timing based on a simplified version of the Ozette sockeye life history model. Beach spawning sockeye life histories are presented independently from tributary spawning subpopulations during their spawning, incubation, emergence, and dispersal phases.

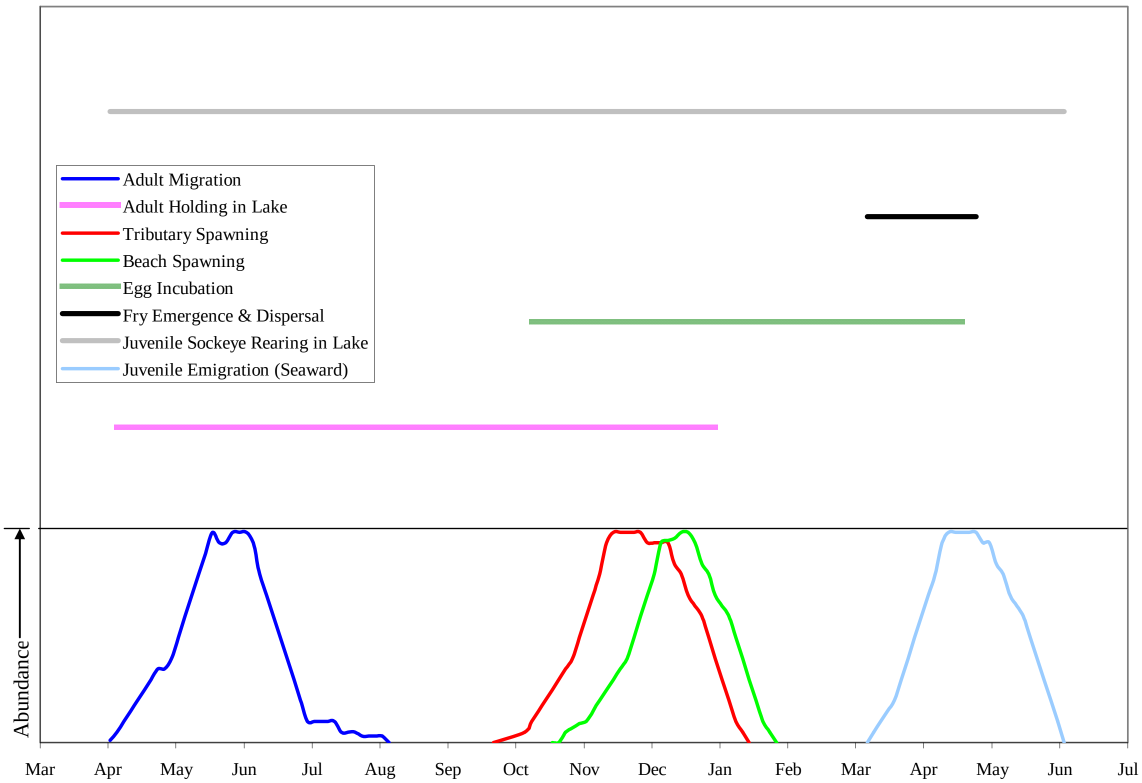

Figure 2.5. Conceptualization of Lake Ozette sockeye life history and timing (modified from Jacobs et al. 1996; note migration, tributary spawning, beach spawning, and smolt emigration are scaled to the estimated relative abundance of animals displaying a life history trait through time, whereas holding, incubation, emergence, and rearing are plotted without a scale of relative abundance.)

2.4 LAKE HYDROLOGY

The hydrology of Lake Ozette has been poorly studied over the contemporary settlement period, but an assortment of lake level, climate, and hydrology data have been collected at various locations in the watershed and coastal region. These data were brought together for the Limiting Factors Analysis (Haggerty et al. 2007) to highlight major physical patterns. A stage gage at the lake outlet has been maintained semi-consistently from 1976 to 2006. Correlated with regional precipitation patterns, Lake Ozette level (which has a range of 12 ft) is typically at its maximum between December and February and its minimum in September. Peak lake stages are highly correlated with total winter rainfall, while minimum lake stages are highly correlated with total summer rainfall and evaporation. During windy periods, lake stage can vary by up to 0.5 feet from north to south because of wind seiche (a long “standing wave” that oscillates from one end of the lake to the other, lasting several hours to days). Lake Ozette stage levels are also considerably influenced both by hydraulic roughness (created, for example, by large woody debris) in the lake outlet, and by the influence of vegetation and land surface disturbance on tributary inflow.

The hydrology of the Ozette watershed and Lake Ozette is complex and controlled by several variables, which can be affected by natural and human-caused factors. Logjams in the upper one mile of the Ozette River can exert a major hydraulic influence on lake stage. Wood removal beginning with the onset of homesteading (1890s) and continuing until the mid-1980s is thought to have significantly affected lake levels. However, Herrera (2005) was unable to determine the precise amount that low, median, or peak lake levels have declined or changed from pre-settlement conditions. Over the last 30 years, LWD has been very slowly accumulating and recovering from past removal but is still assumed to be only a fraction of its historical abundance. It is also well established that delivery of fine sediment to the lake from tributaries has increased during the last 50 to 100 years (Herrera 2006). Current sediment production rates are estimated to be more than three times greater than pre-disturbance production rates (Herrera 2006).

2.5 SPAWNING HABITAT

Olsen’s and Allen’s beaches are the only two remaining Lake Ozette beach spawning locations. The number of beach spawning aggregations that have been entirely eliminated remains unknown. Currently used spawning habitat at Olsen’s and Allen’s beaches, plus the available but currently unused spawning habitat along these two beaches, appears unable to produce more than a fraction of the population that is thought to have once occupied the lake.

Baby Island and Umbrella Beach are of considerable interest because of historical observations of sockeye spawning at these locations (Baby Island in 1994 and Umbrella Beach in 1981), although spawning has not been observed at either place in recent years. Factors that may affect beach and shoreline sediment conditions at both spawning beaches are not well understood, but include alterations of the lake’s hydro-period, colonization of native and non-native vegetation, and reduced numbers of sockeye spawning on the beach. In the case of Olsen’s Beach, potential additional factors include increased sediment delivery from nearby tributaries and shoreline development.

At mid- to upper elevations of both spawning beaches, sedges, sweet gale, and other vegetation occupy much of the beach area. Meyer and Brenkman (2001) noted that sweet gale, grasses, and sedges were observed at depths of up to 2 meters in December 1994, in the vicinity of where sockeye salmon were spawning. Seeps and springs have been mapped on both Olsen’s and Allen’s beaches, and appear to be areas where spawning activity is concentrated. To date no comprehensive inventory of seeps and springs has been completed for Lake Ozette.

A preliminary comparison of shoreline vegetation and sediment dynamics based on aerial photography in 1953 and 2003 (Ritchie 2005) found that significant increases in vegetation cover along the Ozette shoreline likely occurred in the last 50 years. Changes were particularly noticeable along the north end of the lake and near the mouth of Umbrella Creek.

It is important to note that current and recent spawning locations, as well as vegetation and substrate conditions along the lake shoreline, may not be representative of past spawning distribution and shoreline conditions. The historical spawning distribution of beach spawning sockeye is not fully understood. Kemmerich (1926) stated that "The shores of the lake afford many ideal spawning beds and over a large area, also numerous small streams of gravel bottom empty into the lake, which are ideal spawning beds." Kemmerich (1939) also recalled that, "We made no special investigations of spawning beds during the years [1923-1926] but merely observed from time to time that most of the spawning seemed to be along the lake shore in suitable places and especially at the mouths of the several creeks." Dlugokenski et al. (1981) observed sockeye spawning to the north Umbrella Creek during surveys in the late 1970s, but no sockeye have been observed spawning there since, despite exhaustive surveys. The spawning at the mouths of creeks described by Kemmerich (1939) is no longer observed. Meyer and Brenkman (2001) also observed sockeye spawning at Baby Island during the winter of 1994, but no sockeye have been observed spawning there since, also despite exhaustive surveys.

From the above historical observations and known habitat use by sockeye throughout their range, a larger picture of spawning habitat potentially used by sockeye in Ozette can be developed. Beach spawning habitat quality is controlled by substrate size and composition (i.e., gravel with interstitial spaces, low percentage fines), and intergravel circulation from lake current patterns (Blair and Quinn 1991; Hendry et al. 1995; Leonetti 1997) or upwelling hyporheic - and/or groundwater (Blair et al. 1993; Burger et al. 1995; Young 2004). Historically, high quality spawning habitat was likely provided by numerous hydrogeomorphic situations:

1. Spawning on shallow non-vegetated beaches with suitable clean substrate exposed to wind-driven currents and wave action (Leonetti 1997).
2. Spawning at or near upwelling springs or seeps (hyporheic water or groundwater), regardless of water depth, where temperature regimes and intergravel flow are maintained. This reduces mortality during redd dewatering in shallow areas (Burger et al. 1995) or during times of little or no wind-driven current in deeper waters (Leonetti 1997).
3. Spawning at or near tributary inlet (deltas) with suitable substrate (deltaic gravel deposits), good intergravel circulation (upwelling hyporheic water and/or groundwater), and stable hyporheic temperature regimes (e.g., Umbrella Beach: Dlugokenski et al. 1981). Hyporheic water temperature regimes in tributary deltas would likely be slightly warmer and more stable than tributary temperatures, but cooler than ambient lake temperatures or groundwater (White 1993; Edwards 1998).
4. Spawning in tributaries above deltaic zones.

The degree to which spawning habitat has been reduced has not been quantified for the entire lake shoreline. However, the findings of Herrera (2005, 2006) strongly suggest that mean lake level during the beach sockeye spawning period has been lowered by 1.5 to 3.3 feet from historical levels. Lowered mean lake levels during the spawning and incubation periods directly result in decreased beach spawning area. Herrera (2005, 2006) was unable to fully quantify the percent of habitat lost due to lowered lake levels.

Seasonal lake level changes are known to directly result in sockeye redd dewatering. This occurs when sockeye spawn in November, December, and January at elevations along the beaches that become exposed by lower lake levels before incubation and emergence. Peak spawn-timing, depth of spawning, and lake level at emergence are all important factors that influence the degree to which redd desiccation will occur. Years with early high lake levels (November and December) that coincide with peak spawn timing followed by lower than average late winter and early spring months likely result in more significant redd desiccation events. It is unclear what effect the long-term role of LWD removal or land use effects on hydrology has on timing or rate of seasonal lake level changes.

2.6 OZETTE WATERSHED LAND USE

For thousands of years prior to European settlement, the area around Lake Ozette was occupied by Native Americans. It is known that the prairies west of Lake Ozette were regularly burned by Native Americans to maintain open areas, which attracted and fed game such as deer and elk (Wray 1997); however, there is no evidence to indicate other significant or extensive anthropogenic effects on the Ozette watershed before European settlement. Forest fires were infrequent, and mature spruce and cedar trees achieved ages of 400 years and older. In modern times, anthropogenic effects in the Ozette watershed are primarily caused by timber harvest, road construction and maintenance, residential and agricultural development, tourism development, and stream clearing, including past stream improvement projects and policies implemented by Washington Department of Fisheries (WDF), and later, Washington State Department of Natural Resources (WDNR).

2.6.1 Historical Settlement

The Ozette watershed was ceded to the United States by the Makah Indian Tribe in the Treaty of Neah Bay in 1855 and the Quileute Tribe in the Treaty of Olympia in 1856. The Ozette group of Makah was also a signatory to the Treaty of Neah Bay. The Makah reservation encompasses 27,265 acres, and the Ozette reservation, located around the site of the historic Ozette Village, consists of 740 acres. The Ozette Village population decreased in 1896, when natives were forced to move to Neah Bay so that their children could attend school (Wray 1997). The Ozette reservation was transferred in trust to the Makah and is now part of the Makah Reservation.

Swan (1869), who may have been the first white man to see Lake Ozette, describes journeying to the lake by trail with a group of natives from the Ozette village. Franz Boas, an American anthropologist who visited the area in the early 20th century, estimated the pre-contact Makah population at 4,000. In interviews in 1935 (Swindell 1941), Makah fishermen described fishing in the Ozette River, the lake, and the tributaries, using a variety of methods.

The Ozette area was opened to homesteading from 1890 to 1897. Settlement peaked near the turn of the century and declined after the creation of the Olympic Forest Reserve; however, that designation in the Ozette area was eliminated in 1902, and the land was again opened for homesteading. Early settlement was concentrated along the shoreline of the lake and the gentle bottomlands of lower Big River. Many homesteaders in the second round of homesteading sold their claims to timber companies, and the resulting ownership patterns merged into large timber holdings. In 1953, the area west of the lake was transferred to the National Park Service as a part of Olympic National Park (ONP). Lake Ozette and a thin strip along the eastern shoreline were added to the park in 1976 (Meyer and Brenkman 2001).

2.6.2 Modern Land Ownership and Land Use

An analysis by Herrera (Herrera 2006) categorized land ownership in the watershed as of four types: private, National Park Service (NPS), Washington Department of Natural Resources (WDNR), and the Makah Tribe. Landownership and landownership types are depicted in Figure 2.6. Private land includes large industrial forest landowners and small forest, residential, and agricultural landowners, and makes up approximately 73 percent of the basin. The NPS owns 15 percent of the basin, WDNR owns 11 percent, and the Makah Tribe (Ozette Reservation) owns about 1 percent. Land ownership percentages from Herrera (2006) were adjusted to reflect ownership for the entire basin (including Coal Creek and the Ozette River). Private timber companies own an average of 93 percent of the watersheds of the four largest tributaries to Lake Ozette and the Ozette River (Big River, Crooked Creek, Umbrella Creek, and Coal Creek). With the exception of Big River, zoning within these four sub-basins is 99 to 100 percent commercial forest.

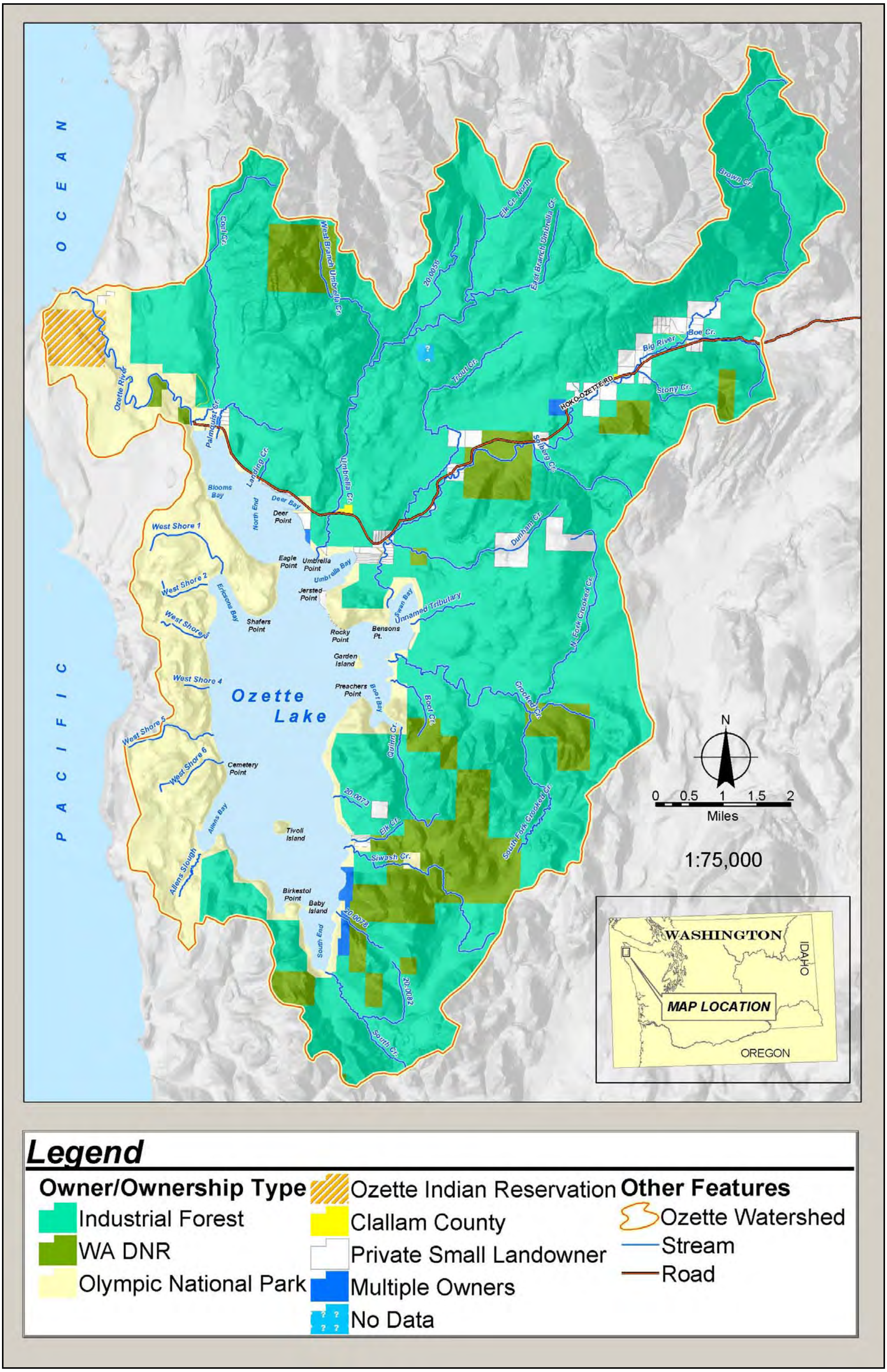

Figure 2.6. Ozette Watershed landownership and landownership type (data source: Clallam County land parcel database). Note: the WDNR ownership along the Ozette River appears to be an error in the County's records.

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2.6.2.1 Olympic National Park

Olympic National Park owns 15 percent of the land in the Lake Ozette watershed, encompassing Lake Ozette and its shoreline, together with much of the land along the Ozette River, except for portions in the Ozette Indian Reservation and parcels managed by DNR (Figure 2.6). Olympic National Park facilities at the lake's outlet include a visitor center, ranger station, campground, and parking area. There are currently 15 cabins on lakefront parcels surrounding the lake within Olympic National Park. In addition to the development at the lake outlet, there are two other vehicle access points to the lake at Swan Bay and Rayonier Landing, along the east side of the north end of the lake. Other developed private properties within the boundaries of Olympic National Park are reachable by boat or trail. The Park provides a variety of recreational opportunities, including camping, fishing, backcountry hiking, canoeing, kayaking, and boating.

2.6.2.2 Timber Harvest and Forest Practices

Since private timberlands make up about 73 percent of the Ozette watershed, their management will play a significant role in sockeye salmon conservation and recovery.

2.6.2.2.1 Timber Harvest History

Commercial timber harvest in the Ozette watershed began in the 1930s (Jacobs et al. 1996). By 1964 over 40 percent of the Big River watershed had been clearcut at least once (Figure 2.7). Until the 1970s, there were few regulations governing timber harvest. Streams were used for yarding corridors, riparian trees were removed, and sediment and slash inputs to streams were not regulated. Dlugokenski et al. (1981) noted that during their habitat surveys, trees were felled across Umbrella Creek and yarded through the channel; they also noted one location in the mainstem where heavy equipment had been operating in the channel. The habitat degradation in Lake Ozette tributaries resulting from past commercial forest operations has long been implicated as a major limiting factor affecting salmonid survival (USFWS 1965; Phinney and Bucknell 1975; Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; WDF et al. 1994; Jacobs et al. 1996; Lestelle 1996; McHenry et al. 1996; MFM 2000; Smith 2000.) Although current regulations and practices have improved, the watersheds still need to heal from legacy effects.

Figure 2.7 depicts the percentage of old growth forest clear-cut through time for the Ozette watershed, as well as the Umbrella Creek, Big River, and Crooked Creek subbasins. An additional analysis was conducted to determine the cumulative percentage of the forested watershed area where second growth forest has been clear-cut. As of 2006, approximately 14.4 percent of the second growth forest within the Ozette watershed had been clear-cut. As of 2006, within the Umbrella Creek, Big River, and

Crooked Creek subbasins, approximately 11.8 percent, 18.2 percent, and 11.2 percent of the second growth forests, respectively, had been clear-cut.

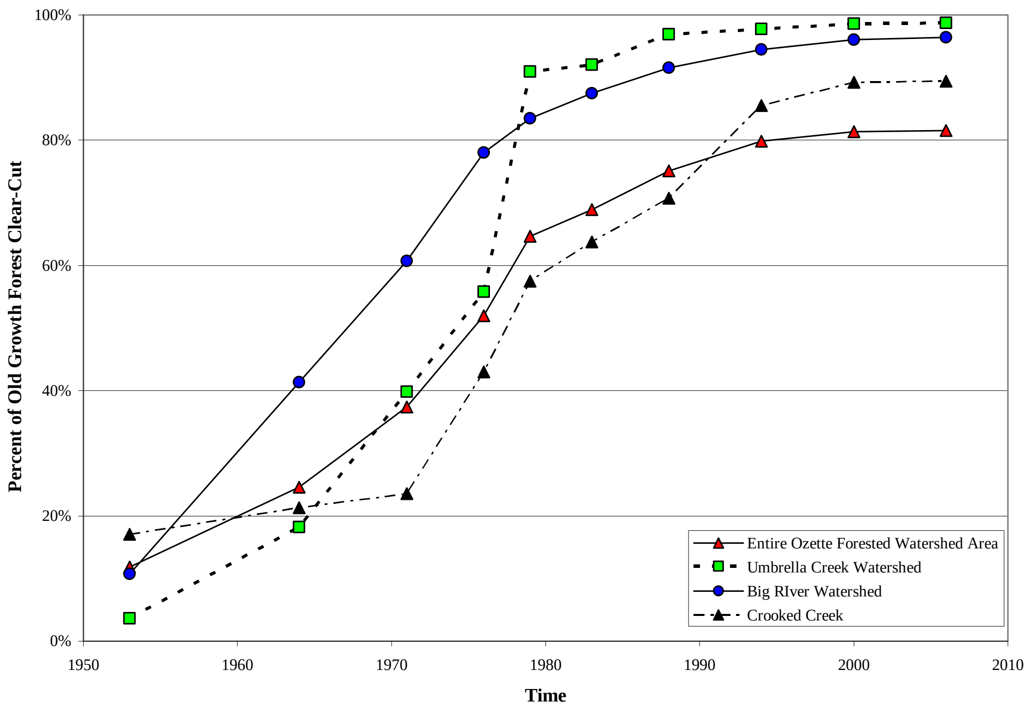

Figure 2.7. Percentage of old growth forest clear-cut through time for the entire forested portion of the Ozette watershed, as well as the Umbrella Creek, Big River, and Crooked Creek subbasins (source: Haggerty et al. 2007).

2.6.2.2.2 Washington State Department of Natural Resources

Statewide, Washington's Department of Natural Resources (DNR) manages over 5.5 million acres of state-owned lands:

- 3 million acres of the state's trust lands—forests, range, and agricultural lands, and commercial properties—managed to earn revenue to help fund construction of public schools and universities; provide diverse habitat; and provide public recreational opportunities.
- 2.6 million acres of 'aquatic' lands—the marine beds of Puget Sound, Straits of Juan de Fuca and coast, many tidelands and beaches, and navigable lakes and rivers across the state—managed to protect aquatic ecosystems, encourage navigation and commerce, offer public access, and allow sustainable use of renewable resources such as shellfish.
- 31,000 acres in 52 Natural Area Preserves and 92,000 acres in 29 Natural Resources Conservation Areas that protect outstanding examples of ecosystem diversity, often protecting features unique to Washington State.

In the Ozette Basin, which includes state trust lands in the Olympic Experimental State Forest, DNR manages 11 percent of the land base. Stewardship of forested state trust lands in the Experimental Forest is guided by the 1997 multi-species Trust Lands Habitat Conservation Plan, an agreement with NMFS and U.S. Fish and Wildlife Services under the ESA. The conservation plan helps DNR conserve and enhance habitat for Federally listed species such as the northern spotted owl, marbled murrelet, and salmon, as well as other native fish and wildlife. (See next section.)

2.6.2.2.3 Habitat Conservation Plans (HCPs)

Under ESA section 10, states, local governments, and private landowners may apply for an Incidental Take Permit for otherwise lawful activities that may harm species listed as endangered or threatened, or their habitats. To obtain a permit, an applicant must submit a Habitat Conservation Plan (HCP) outlining what he or she will do to minimize or mitigate the impact of the permitted take on the listed species. NMFS and the USFWS usually work together with potential applicants to address all currently listed species, plus fish and wildlife species that may someday require ESA protection. The two services coordinate with applicants to ensure use of the best available science while developing HCPs. Commercial forestry in the Ozette watershed is managed under two HCPs: the Forest Practices HCP, or FPHCP, which applies to private commercial timberlands regulated by State Forest Practice Rules; and the Washington Department of Natural Resources (DNR) HCP, which applies to state-owned timber lands managed by the DNR.

Forest Practices Habitat Conservation Plan

In 1999, the Washington State Legislature passed the Salmon Recovery Funding Act (Engrossed Senate House Bill 5595), which identified forest practices as a critical component for salmon recovery. Through the Act, the Legislature recognized a report known as the Forests and Fish Report (FFR) as being responsive to its policy directive for a collaborative, incentive-based approach to support salmon recovery. The FFR was developed to create forest practices prescriptions that would protect riparian and aquatic habitat for the conservation of listed salmon species and other unlisted fish and stream associated amphibian species. The groups that contributed to the development of the FFR included state agencies (DNR, Washington Department of Fish and Wildlife [WDFW], Washington Department of Ecology [DOE], and the Governor's Office), Federal agencies (USFWS, NMFS, EPA), certain Washington Tribes and the Northwest Indian Fisheries Commission, the Washington State Association of Counties, the Washington Forest Protection Association (WFPA), and the Washington Farm Forestry Association (WFFA).

In 1999, the Washington State Legislature also passed the Forest Practices Salmon Recovery Act (Engrossed Senate House Bill 2091), which directed the Washington Forest Practices Board to adopt new forest practices rules, encouraging the Forest Practices Board to follow the recommendations of the FFR. In its rulemaking procedures, the Forest Practices Board conducted an evaluation of the FFR, as well as alternatives to the FFR. This evaluation included an Environmental Impact Statement (EIS) under the Washington State Environmental Policy Act (SEPA). The Final State Environmental Impact Statement, entitled Alternatives for Forest Practices Rules for Aquatic and Riparian Resources, was published in April 2001. The Forest Practices Board adopted new permanent forest practices rules in 2001 based on the FFR. As directed by the Washington State Legislature, through the Forest Practices Salmon Recovery Act, Governor Gary Locke designated the Commissioner of Public Lands to negotiate on behalf of the State of Washington with the relevant Federal agencies to satisfy Federal requirements under the ESA pursuant to the Revised Code of Washington (RCW), Chapter 77.85.190(3).

Beginning in 2001, the State began working closely with USFWS and NMFS to develop what has become the Forest Practices Habitat Conservation Plan (FPHCP), under section 10(a)(1)(B) of the ESA, based on the forest practices rules adopted in 2001. On February 9, 2005, the State submitted a formal application for Incidental Take Permits (ITPs). In June 2006, NMFS and the U.S. Fish and Wildlife Service issued ITPs to the State of Washington that incorporated the terms of the FPHCP. In approving the ITP (which also covers Lake Ozette sockeye salmon) NMFS found implementation of the FPHCP "consistent with the long-term survival and recovery of covered species" (NMFS 2006). NMFS' approval of the FPHCP includes an extensive record that describes how implementing the conservation measures in the FPHCP will likely contribute to recovery of watershed processes that support salmon and trout statewide.

The FPHCP covers 16 listed threatened and endangered species under NMFS' jurisdiction, including Lake Ozette sockeye. The administrative framework of the FPHCP allows for the development, implementation, and refinement of the state's Forest Practices program, including creation of new Forest Practices Rules and guidance, administering forest practices permitting, performing compliance monitoring, and taking enforcement action. An additional part of the process was the concept of refining forest practices based on adaptive management. The science-based compliance monitoring and adaptive management programs included in the FPHCP allow evaluations of plan effects and changes to environmental protections to take place over time as more is learned regarding the plan's effectiveness in promoting recovery of ESA listed salmon populations. Details of the FPHCP are summarized at *http://www.nwr.noaa.gov/Salmon-Habitat/Habitat-Conservation-Plans;washington-Forest-Practices/Index.cfm.*

Washington Department of Natural Resouces Habitat Conservation Plan

In 1999, NMFS issued the Washington Department of Natural Resources an Incidental Take Permit under ESA section 10, based on the HCP approved in 1997. The WDNR HCP covers all forested state trust lands in western Washington. The Riparian Forest Restoration Strategy (RFRS), developed with the Services and approved in 2005, defines the management goal for riparian areas as the restoration of high quality habitat to aid in salmon recovery efforts and to contribute to the conservation of other aquatic and riparian dependent species. Riparian management includes various types of thinning and also the natural development of some unmanaged areas to result in restoring structurally complex older riparian forests. Details of the RFRS are described in a document available at: http://www.dnr.wa.gov/ResearchScience/Topics/TrustLandsHCP/Pages/hcp_rfrs_implement.aspx

2.6.2.3 Private Residential and Agricultural Development

There are currently 15 cabins/homes on lakefront parcels surrounding the lake. The area around the lake outlet was developed into a resort in the 1950s, and was redeveloped into the ONP Ozette visitor center, ranger station, campground, and parking area in the 1980s. Currently, this is the most developed part of the lake shoreline. The developed length of shoreline comprises approximately 1-2 percent of the total shoreline length.

Along Big River, agricultural and residential development has been confined to the lower 10 miles of the river. Most residential development along Big River is near the original wagon trail. Currently, about 245 acres of land (~1.2 percent of the watershed area) are cleared for residential or agricultural use, and there are approximately 62 houses and other buildings within the Big River valley. In agricultural areas, the riparian zone and floodplain of the river were cleared of vegetation and converted to pasture. Currently, approximately 9,900 feet of Big River shoreline are adjacent to developed residential or agricultural land.

2.6.2.4 Makah Tribe- Ozette Reservation

The Ozette Reservation encompasses Cape Alava and 1.11 miles of coastal shoreline, and extends eastward, containing nearly 0.7 miles of the Ozette River. The 740-acre reservation is currently managed as a cultural management zone by the Makah Tribe.

2.6.3 Roads

Lake Ozette in 1923 was described by Kemmerich (1926) as being “isolated” by its location “25 miles from Clallam Bay over an almost impassable road.” The first road to Lake Ozette was completed in 1926 (Jacobs et al. 1996) and thereafter road and railroad building kept pace with timber harvest in the watershed. In 1935, approximately 12.8 miles of road or railroad grade are shown on the USGS map. This increased to 25 miles in 1956, and by 1987 the USGS maps show 258.5 miles of road. Road delineation using aerial photos and mapping in GIS resulted in the estimates of road length and road densities for major subbasins depicted in Figure 2.8. In 2006, the total length of roads within the Ozette watershed was 417 miles. This road length results in an overall watershed road density of 5.5 mi/mi^2 (excluding the surface area of the lake). The 2006 orthophoto coverage indicates that road densities on non-Federal land exceed 6 mi/mi^2 within the Ozette watershed.

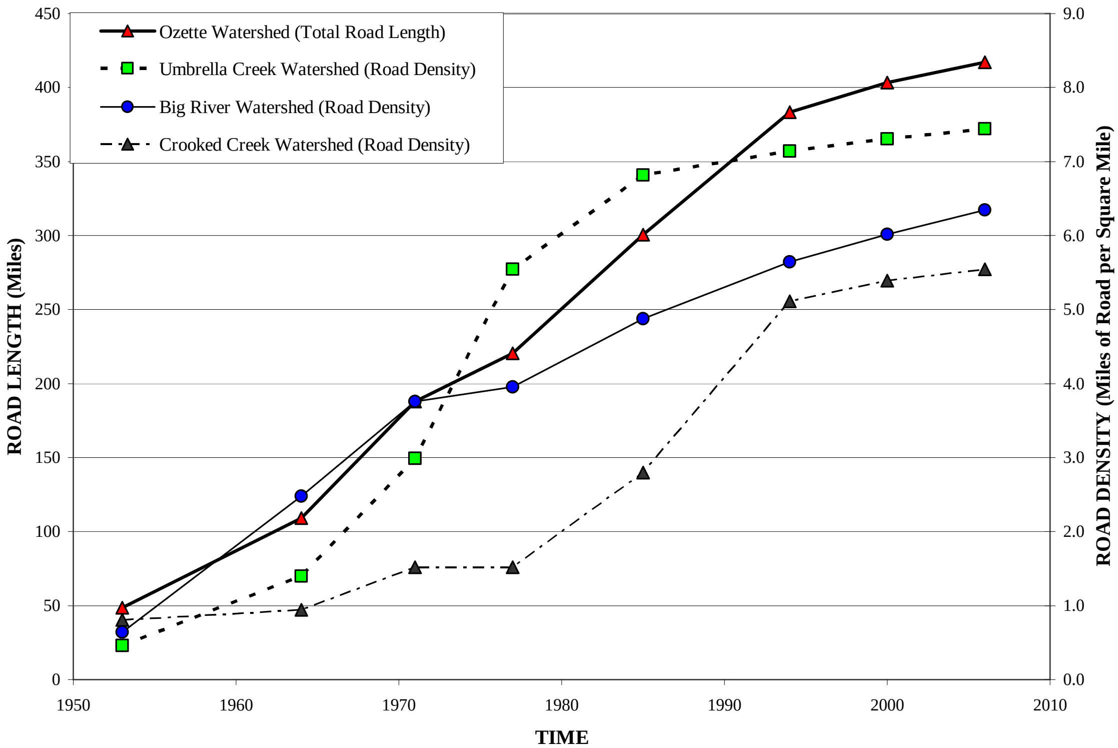

Figure 2.8. Ozette watershed road lengths and road densities for major subbasins through time (road lengths based on aerial photo coverage; basin areas used in road density calculations were generated using a digital elevation model).

The Hoko-Ozette Road is the only significant public road in the area. It follows the original wagon trail to Ozette from Clallam Bay and parallels Big River for approximately 7.8 river miles (Swan Bay Road to Nicolas Road). Within this reach, the road prism is frequently within the floodplain and channel migration zone of Big River. Kramer (1953) reported the road to be "*at times covered with flood waters*" during stream clearing activities in December 1952. Since then, the road has been raised repeatedly, but it still floods periodically. The road functions as a dike or levee during high water in some locations. Approximately 4,100 feet (1,250 meters) of bank hardening occurs along the county road and private property. Approximately 3.06 miles of riparian area are impacted by the road (road length within 200 feet of the bankfull edge of Big River; source: preliminary review of 2003 color aerial photos).

2.7 LAKE OZETTE SOCKEYE ESU CRITICAL HABITAT

The ESA requires the Federal government to designate "critical habitat" for any species it lists under the ESA. The Act defines critical habitat as areas that contain physical or biological features that are essential for the conservation of the species, and that may require special management or protection. Critical habitat designations must be based on the best scientific information available, in an open public process, within specific timeframes. On September 2, 2005, NMFS published a final rule (70 FR 52630) to designate critical habitat for Ozette Lake sockeye and 12 other ESUs/DPSs of salmon and steelhead (Figure 2.9). The final rule took effect on January 2, 2006.

A critical habitat designation does not set up a preserve or refuge, and critical habitat requirements do not apply to citizens engaged in activities on private land that do not involve a Federal agency. The designation applies only when Federal funding, permits, or projects are involved. Under section 7 of the ESA, all Federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat. Before critical habitat was designated, careful consideration was given to its economic impacts, impacts on national security, and other relevant impacts. The Secretary of Commerce may exclude an area from critical habitat if the benefits of exclusion outweigh the benefits of designation, unless excluding the area will result in the extinction of the species concerned.

For anadromous fish, the essential features of designated critical habitat include substrate, water quality, water quantity, water temperature, food, riparian vegetation, access, water, velocity, space, and safe passage. These features also describe the habitat factors associated with viability for all ESUs/DPSs. The specific habitat requirements for each ESU/DPS differ by life history type and life stage.

NMFS formally designated the following areas within the Hoh/Quillayute subbasin as critical habitat that is necessary for the survival and recovery of the Ozette Lake sockeye salmon ESU (70 FR 52630, September 2, 2005): Ozette Lake and the Ozette Lake watershed, including the Ozette River (Lat 48.1818, Long -124.7076) upstream to endpoints in: Big River (48.1844, -124.4987); Coal Creek (48.1631,-124.6612); the East Branch of Umbrella Creek (48.1835, -124.5659); North Fork Crooked Creek (48.1020, -124.5507); Ozette River (48.0370, -124.6218); South Fork Crooked Creek (48.0897, -124.5597); Umbrella Creek (48.2127, -124.5787); and three unnamed Ozette Lake tributaries (48.1771, -124.5967; “Hatchery Creek”- WRIA 20.0056); (48.1740, -124.6005; tributary to Umbrella Creek); and (48.1649, -124.5208; “Stony Creek”). See Figure 2.9 for a detailed map depicting designated critical habitat within the Ozette Lake Sockeye ESU.

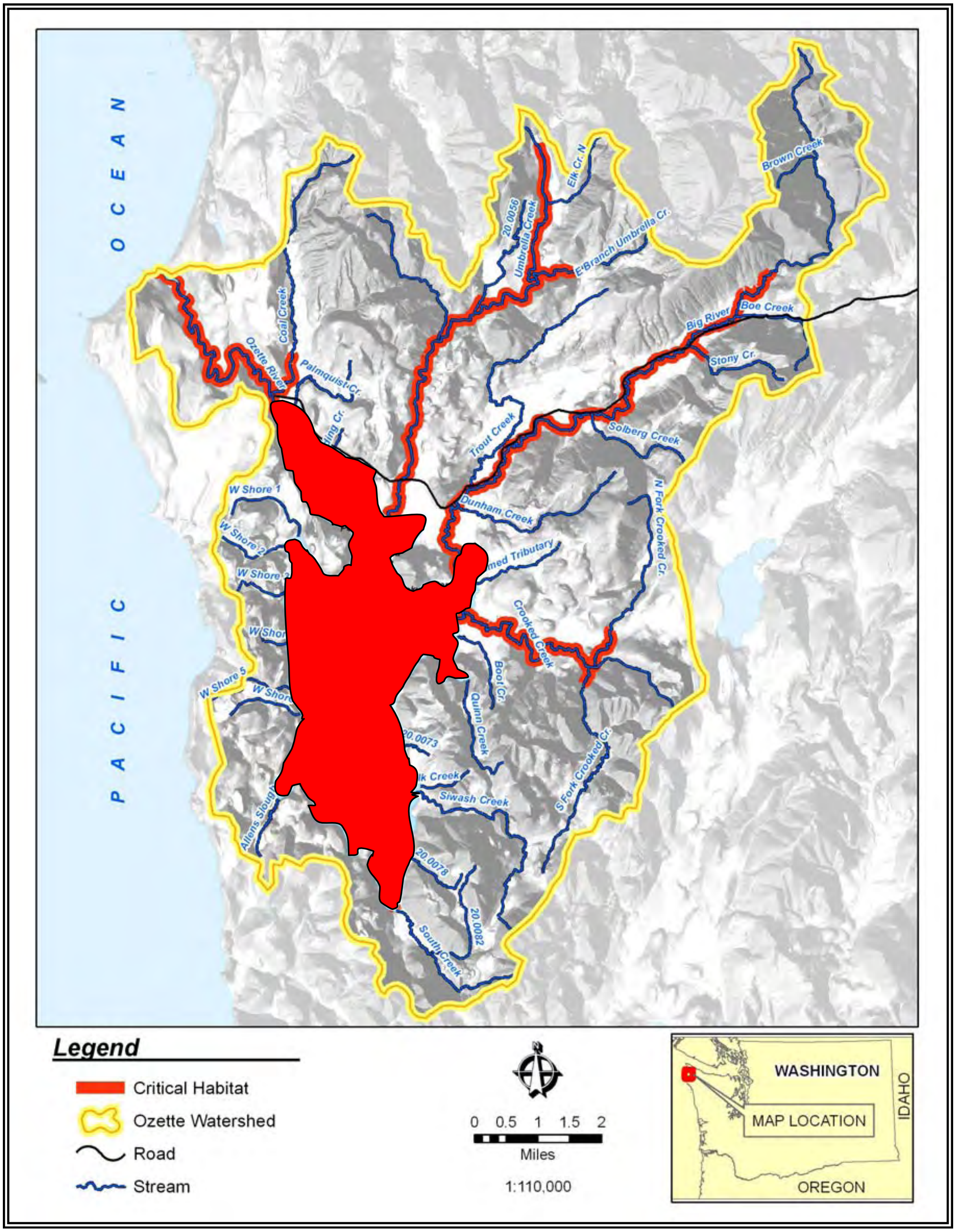

Figure 2.9. Designated critical habitat for Lake Ozette sockeye salmon. Note: the entire lake is designated critical habitat. (Data from: 70 FR 52630, September 2, 2005).

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2.8 LAKE OZETTE SOCKEYE POPULATION STATUS AND ADULT ABUNDANCE TRENDS

The population status and adult abundance trends for Lake Ozette sockeye have been investigated and summarized recently in several reports (Jacobs et al. 1996; Gustafson et al. 1997; NMFS 1998; MFM 2000; Good et al. 2005; Haggerty et al. 2007). Low numbers of adult Lake Ozette sockeye returning to spawn, documented in studies conducted as part of NMFS' ESA status review and listing process (Gustafson et al. 1997; NMFS 1998; and Good et al. 2005), were a primary reason for listing the sockeye as threatened. The steep decline reported in those status reviews is no longer apparent in the abundance data; however, this fact can be attributed largely to the recent increase in the number of tributary-spawning sockeye. The most recent 4-year average abundance estimate was just over 4,600 sockeye (Haggerty et al. 2007 [return years 2000-2003]), still considerably lower than historical numbers.

The NMFS status reviews are summarized in Section 2.8.1. More recent, detailed adult sockeye abundance data and adult run-size estimates, spawning aggregation escapements, and recent and long-term trends in both total run sizes and spawning aggregation abundance can be found in the Limiting Factors Analysis (Haggerty et al. 2007). These recent data are summarized in Section 2.8.2.

2.8.1 NMFS Status Reviews

The three most recent status reviews of Lake Ozette sockeye (Gustafson et al. 1997; NMFS 1998; Good et al. 2005) differed only slightly in emphasis; all agreed that overall abundance is low, that degraded habitat conditions represent a limiting factor for this ESU, and that more data are needed. This section briefly summarizes the findings of the three reviews.

2.8.1.1 Biological Review Team 1997 (Gustafson et al. 1997)

In 1997, the West Coast Sockeye Biological Review Team (BRT), made up of scientists from the NMFS Northwest Fisheries Science Center, determined that Lake Ozette sockeye are distinct from other Washington sockeye salmon populations and that they represent a unique evolutionarily significant unit (ESU) (Gustafson et al. 1997). The BRT reported that at the time of the status review, Lake Ozette sockeye escapements averaged less than 1,000 fish per year and had little room for further declines before abundance would be critically low. The BRT found that the 5-year (1992-1996) average abundance was only 700 adult sockeye and that the population was declining at a rate of 10 percent per year. They concluded that if present conditions (those observed in the early and mid-1990s) were to continue, Lake Ozette sockeye were likely to become in danger of extinction in the foreseeable future.

The BRT identified several major concerns that led to their finding of danger of extinction in the foreseeable future:

- Siltation of beach spawning habitat
- Very low adult abundance relative to harvest in the 1950s
- Overall downward trend coupled with large fluctuations in abundance
- Potential genetic effects of ongoing hatchery production and past practices of sockeye salmon being interbred with genetically dissimilar kokanee

2.8.1.2 Biological Review Team 1998 (NMFS 1998)

In late 1998, the BRT met to discuss new information and comments received regarding their earlier determinations concerning the status of the Lake Ozette and Baker Lake sockeye salmon ESUs. The BRT received adult migrant abundance data for return years 1997 and 1998 from the Makah Tribe. These data were then pooled with data used in the 1997 status review. The five-year geometric mean estimated abundance for the period 1994-1998 was 580, slightly below the average of 700 reported by Gustafson et al. (1997). The BRT concluded that this decrease was largely due to the fact that the earlier average included two dominant brood-cycle years, while the recent average included only one. The BRT found that the return year 1998 minimum count of 984 was substantially above the count of 498 that was observed 4 years (one generation) earlier, and that this was likely the result of a change in counting methods (time lapse video) and expanded operation of a weir in the Ozette River near the lake outlet (resulting in a more complete count of the sockeye salmon run).

During the updated population trend analysis, the BRT found that the short-term (10-year) trend had improved from a "precipitous" decline of 10 percent per year (Gustafson et al. 1997) to a relatively low 2 percent annual increase. The BRT could not determine how much of the "improvement" or change was due to the influence of enhanced enumeration methods. The BRT also found that the long-term trend remained slightly downward at minus 2 percent per year. The BRT concluded that the Lake Ozette sockeye salmon ESU was not in danger of extinction. However, the BRT further stated that, "*…if present conditions continue into the future*, *it [*the Lake Ozette sockeye ESU*] is likely to become endangered in the foreseeable future*." There was a moderate level of uncertainty around the BRT's conclusions because of uncertainties regarding the reliability of adult sockeye abundance estimates and the historical presence of river-spawning sockeye salmon.

The BRT concluded, "Current escapements averaging below 1,000 adults per year imply a moderate degree of risk from small population genetic and demographic variability, with little room for further declines before abundances reach critically low levels." Additional perceived risks to the ESU included the following:

- Low current adult abundance

- Trends and variability in adult abundance
- Overall downward trend coupled with large fluctuations in abundance
- Siltation of beach spawning habitat
- Very low adult abundance relative to harvest in the 1950s
- Potential genetic effects of past interbreeding with genetically dissimilar kokanee

2.8.1.3 Biological Review Team 2005 (Good et al. 2005)

In June 2005, the BRT completed an updated status review of 28 West Coast salmon and steelhead ESUs (Good et al. 2005). The review for Lake Ozette sockeye included the following biological categories: population structure, population status data (e.g., adult abundance, run timing, spawning distribution and disposition), threats to viable salmonid population (VSP) parameters, and previous BRT conclusions.

The BRT concluded that the Lake Ozette sockeye salmon ESU is composed of one historical population, with substantial substructuring of individuals into multiple spawning aggregations. The BRT determined that the existing spawning aggregations spawn in two beach locations (Allen’s Beach and Olsen’s Beach) and in two tributaries (Umbrella Creek and Big River). (Note: The BRT did not include Crooked Creek as a discrete spawning aggregation.) The BRT postulated that there were probably more beach spawning aggregations historically, but it is not possible to determine how many subpopulations existed previously.

Adult sockeye run-size estimates were revised upwards after the 1997 status review because of methodological changes in sockeye enumeration and run size estimation. The most significant change was the use of 24-hour per day monitoring of the weir in the Ozette River near the lake outlet, using underwater time-lapse video instead of 6- to 8-hour per day human observers. Run sizes used in the 2005 updated status review were provisional, adjusted based on assessments of human error and inter-annual run timing. The new estimates are included in Section 2.8.2.2. The improved enumeration and estimation methods still include a significant level of uncertainty, which suggests that methods used before 1998 are likely even more unreliable. The current trends in abundance are unknown for the beach spawning aggregations. The BRT concluded that the overall abundance had declined from historical levels; whether this decline resulted in fewer spawning aggregations, lower abundances at each aggregation, or both, is not known.

The BRT included an updated threats review based upon work conducted by Makah Fisheries Management (MFM) and the Lake Ozette Sockeye Steering Committee, with primary sources of threats to VSP parameters listed as follows:

- Loss of adequate quality and quantity of spawning and rearing habitat
- Predation and disruption of natural predator-prey relationships
- Introduction of nonnative fish and plant species

- Past overexploitation
- Poor ocean conditions
- Interactions among those factors

The majority of BRT members (70 percent) categorized the Lake Ozette sockeye salmon ESU as “likely to become endangered.” The remainder were split equally between the categories of “in danger of extinction” or “not likely to become endangered.” The BRT noted that a risk assessment for this ESU continues to be hampered by incomplete data. Recent evaluations have cast even more doubt on the usefulness of population data prior to 1997. However, the BRT concluded, “It appears that overall abundance is low for this population, which represents an entire ESU, and may be substantially below historical levels.” The BRT also voiced concerns about habitat degradation in the lake resulting in the loss of numerous sites suitable for beach spawning.

2.8.2 Recent Data on Adult Sockeye Population Size and Trends

Detailed adult sockeye abundance data, adult run-size estimates, spawning aggregation escapement estimates, and estimated recent and long-term trends in both total run sizes and spawning aggregation abundance can be found in the Lake Ozette Sockeye LFA (Haggerty et al. 2007). The following is a summary of data and estimates that will serve as the baseline for the analysis of limiting factors and consideration of recovery actions in this recovery plan.

2.8.2.1 Historical (Pre-1977) Adult Sockeye Run Sizes

Very few data are available for estimating historical escapement levels for Lake Ozette sockeye salmon. A weir was used to enumerate sockeye salmon entering Lake Ozette in 1924, 1925, and 1926, but no harvest data for interceptory fisheries are available for those years (see Figure 2.10). In addition, these are only partial counts that do not incorporate the entire run-time window for Lake Ozette sockeye.

Between 1948 and 1976, harvest data are available but no escapement data were collected, creating substantial uncertainty regarding run sizes during this period (see Figure 2.10). Makah Fisheries Management (2000) questioned the accuracy and reliability of the reported harvest numbers, since they came from verbal reports of fish bought by local fish buyers. However, Washington Department of Fisheries (1955) cites the source of the catch data along with the numbers of nets used in the Ozette River fishery. It can still be argued that in some years the harvest may have been significantly less, and in other years more, considering that much of the harvest may not have been sold and consequently not reported. Blum (1988) speculated that the Lake Ozette sockeye run exceeded 50,000 fish prior to the 1940s. In any case, over a 20-year period, Lake Ozette sockeye harvests went from several thousand per year to zero because of decreasing sockeye abundance.

For the last 20-plus years (1982-present) no harvest of Lake Ozette sockeye salmon has taken place in tribal fisheries. From 1973 to 1977, tribal regulations strictly limited harvest of sockeye salmon. Reported catch during this 5-year period was 133 fish. From 1978 through 1982, tribal regulations limited the harvest to 30 fish per year for ceremonial purposes.

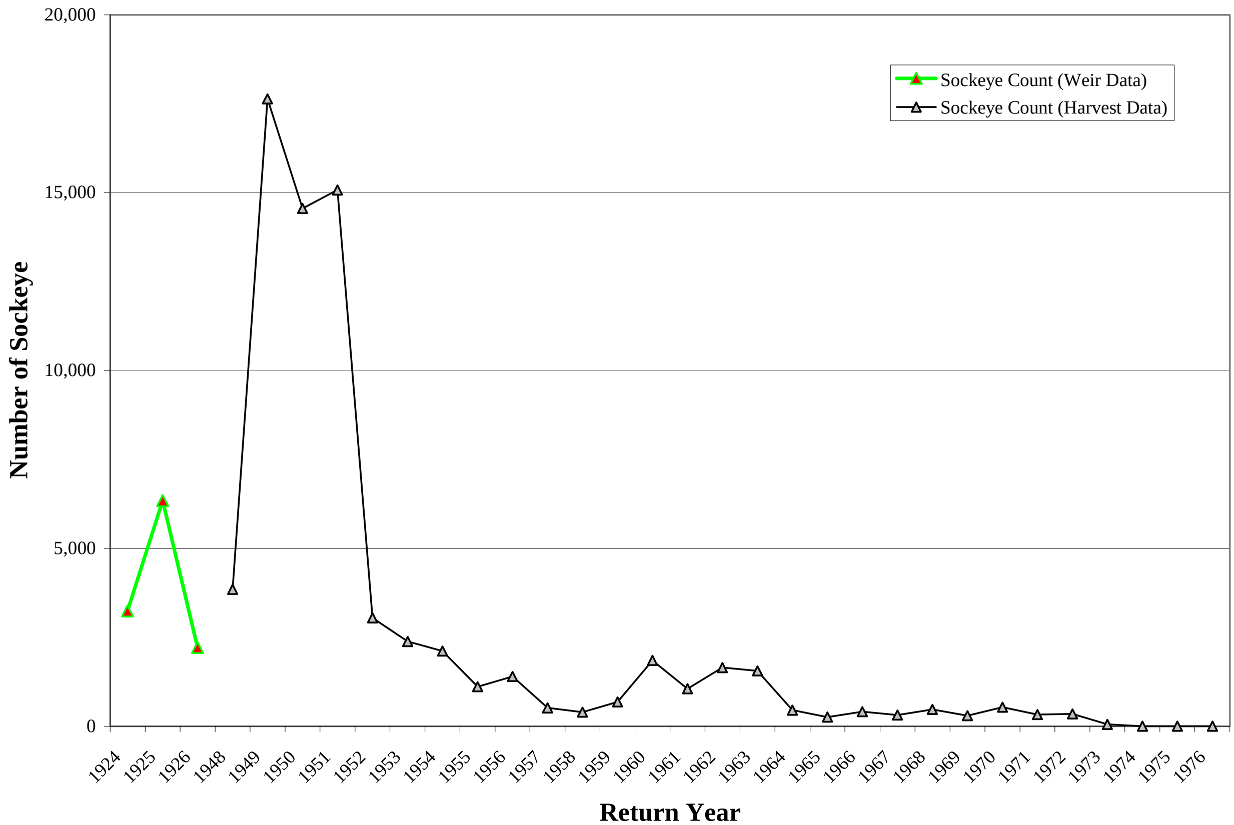

Figure 2.10. Historical abundance of Lake Ozette sockeye (RY1924-1926 and RY1948-1976) based on Kemmerich (1945) and Jacobs et al. (1996).

2.8.2.2 Recent (1977-2003) Adult Sockeye Run Sizes

The first contemporary attempt to quantify the Lake Ozette sockeye adult run size occurred between 1977 and 1980, when a joint study between the U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), and the Makah Tribe operated a counting weir in the Ozette River, near the lake's outlet. Lake Ozette sockeye run sizes from 1977 to present are considered "recent" estimates within the context of this discussion. The methods used to enumerate and estimate Lake Ozette sockeye run sizes have changed significantly between 1977 and the present. Incorrectly applied critical assumptions that were part of the older methods limited the quality of data collected and likely underestimated run sizes (see MFM 2000; Haggerty et al. 2007). A thorough review of adult sockeye enumeration methods used in recent years (1977-2003) is included in the Lake Ozette Sockeye LFA (Haggerty et al. 2007). Estimated adult Lake Ozette sockeye salmon run sizes presented in Jacobs et al. (1996) and MFM (2000) for the period 1977 to 1999 are depicted in Table 2.2. MFM (2000) used information and data collected in 1998 and 1999 to adjust run-size estimates between 1988 and 1997.

Haggerty et al. (2007) reexamined pre-1998 datasets and run-size estimates in order to compare the most recent run-size estimates with those made in the past (e.g., Jacobs et al. 1996; MFM 2000). Common factors such as run timing and visual sockeye detection rates were used to adjust previous run-size estimates. This was done so that all run-size estimates were based upon the same basic assumptions (day and night transit, run timing, observer error). Two critical variables (run timing and observer error) had to be estimated for pre-1998 datasets. A three-step range was used for each ***unknown*** variable, resulting in nine run-size estimates for each return year (for a complete description of details see Haggerty et al. 2007; Haggerty 2004, 2005a, 2005b, 2005c, and 2005d). The median value of the nine run-size estimates was then defined as the run-size estimate for a given year. Figure 2.11 depicts the newly constructed run-size estimates for return years 1977 through 2003, grouped by brood year. These newly constructed run-size estimates illustrate the high uncertainty for each of the pre-1996 run-size estimates; no discernible trend is present.

Table 2.2. Estimated Lake Ozette sockeye run sizes, monitoring periods, and methods used. For details on methods used see Lake Ozette Sockeye LFA (Source: Haggerty et al. 2007).

YEAR	Weir Operations Start	Weir Operations End	No. Adults Observed	Estimated Run Size (Jacobs et al. 1996)	Estimated Run Size (MFM 2000)	Method of Estimate	Citations
1977	~5/14/1977	~8/10/1977	920 + 84 harvested	1,004	1,004	N = n + Harvest	Dlugokenski *et al.* (1981)
1978	~5/24/1978	~8/8/1978	890 + 30 harvested	920	920	N = n + Harvest	Dlugokenski *et al.* (1981)
1979	~5/20/1979	~8/8/1979	510 + 30 harvested	540	540	N = n + Harvest	Dlugokenski *et al.* (1981)
1980	?	?	255 + 30 harvested	432	432	N = n/p + Harvest	Dlugokenski *et al.* (1981)
1981	6/8/1981	7/8/1981	239		350	N = n/p	MFM 1981a
1982	6/9/1982	8/17/1982	2,061 + 29 harvested	2,147	2,152	N = n + Harvest	Blum 1988
1983	NA	NA	NA	350	NA	NA	No Data Collected
1984	6/19/1984	8/7/1984	804	2,170	2,170	N = n/p	Blum 1988
1985	NA	NA	NA	NA	NA	NA	NA
1986	?	?	NA	691	691	N = n/p	LaRiviere 1991;
1987	NA	NA	NA	NA	NA	NA	NA
1988	6/27/1988	6/29/1988	218	2,191	3,599	N = n/p	LaRiviere 1991
1989	6/19/1989	6/30/1989	143	588	603	N = n/p	LaRiviere 1991
1990	6/7/1990	8/11/1990	175	263	385	N = n/p	LaRiviere 1991
1991	5/23/1991	7/12/1991	NA	684	684	N = n/p	Drange and LaRiviere 1991
1992	5/29/1992	7/9/1992	1,175	2,166	2,548	N = n/p	MFM 2000
1993	?	?	69	≤267	NA	N = n/p	MFM 2000
1994	6/6/1994	7/15/1994	NA	498	585	N = n/p	MFM 2000
1995	?	?	NA	314	314	N = n/p	MFM 2000
1996	6/18/1996	6/29/1996	NA	NA	1,778	N = n/p	MFM 2000
1997	6/9/1997	7/1/1997	280	NA	1,133	N = n/p	MFM 2000
1998	5/7/1998	7/2/1998	980	NA	1,406	MFM 2000	MFM 2000
1999	5/1/1999	9/30/1999	1,945	NA	2,076	MFM 2000	MFM 2000

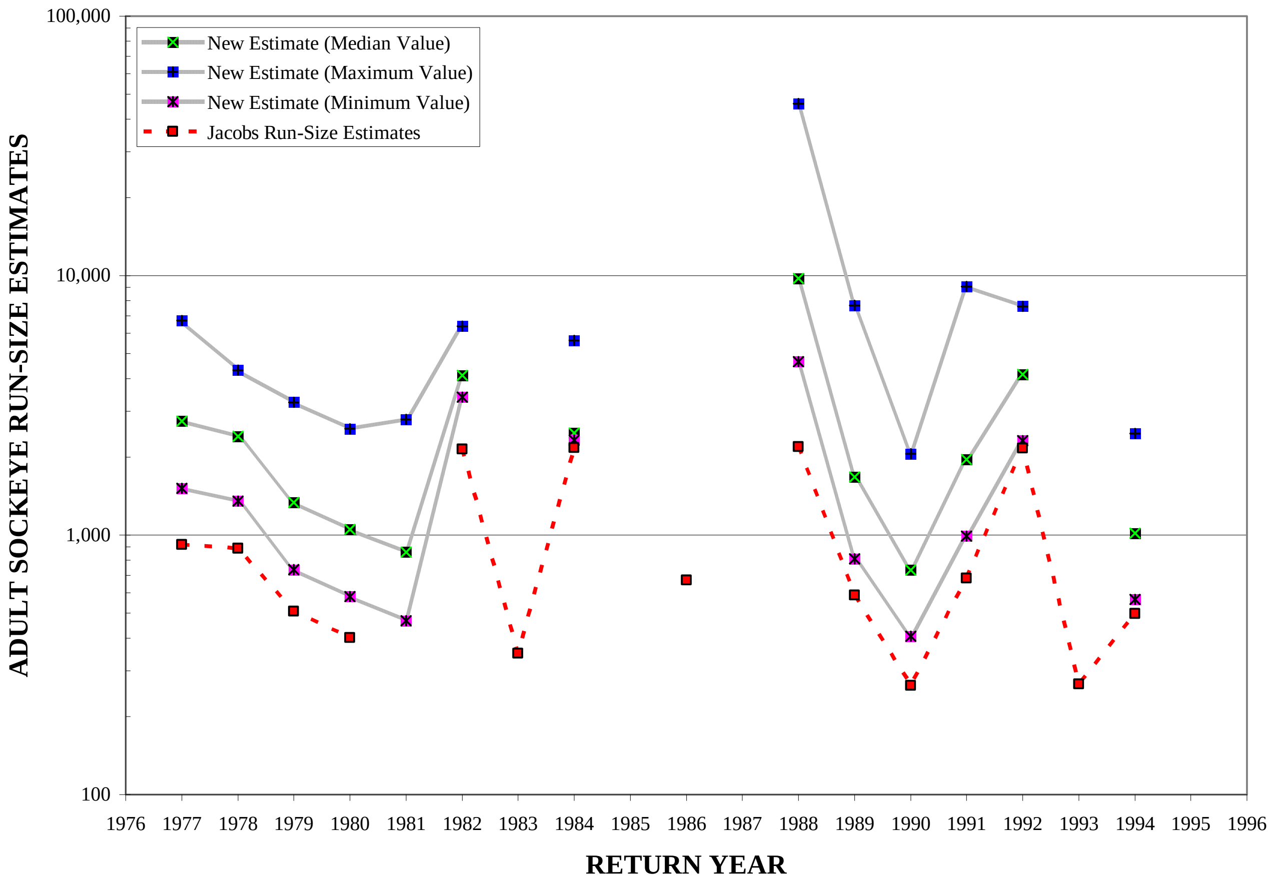

Figure 2.11. Lake Ozette Sockeye run-size estimates for return years 1977-1995, adjusted based on sockeye detection rates and new run-timing curves (from RY 1998-2003) contrasted with estimates reported in Jacobs et al. 1996 (Modified from Haggerty et al. 2007).

The methods used to derive the most recent (1996-2003) run-size estimates are described in detail in Haggerty et al. (2007) and Haggerty (2004, 2005a, 2005b, 2005c, and 2005d). Sockeye run-size estimates from 1996 to 2003 ranged from a low of 1,609 (1997) to a high of 5,075 (2003), averaging approximately 3,600 sockeye per year. The quality of annual run-size estimates varies depending on the methods used to collect data, data quality, and days of data collection. In some years, such as 1996, very few data were collected and their quality was somewhat questionable. The range of reasonable run-size estimates for 1996 is broad (1,924 to 18,117). Consistent run-size estimate methodology was applied to datasets from 1996 through 2003. For example, the run size in each year is calculated based upon a return window starting April 15 and ending August 15. Where small data gaps were present within a given dataset, a two-sided, hourly time step, 7-day moving average method (see Haggerty 2004) was used to expand for missing time periods. Where bigger blocks of missing data were present (such as in 1996 and 1997) sockeye counts were adjusted based upon the mean proportion of sockeye detected by visual observers from the 1998 and 1999 weir datasets (two years when full counts were made by visual observers). Upon adjusting the visual observer counts, the run-size estimate was then expanded based upon the average proportion of sockeye transiting the weir during RY 1998-2003 for the days where visual observer data were collected. Run-size estimates for return years 1996 through 2003 are provided in Table 2.3.

Table 2.3. Estimated adult sockeye run sizes entering Lake Ozette for return years 1996 through 2003 (Source: Haggerty et al. 2007)

Year	Estimated Run size	Confidence in Estimate	Low End Estimate	High End Estimate	Days of Weir Operation	Number of Sockeye Counted	No. of Sockeye Counted to Derive Run-Size Estimate
1996	4,131	Low	1,924	18,117	12	429	429
1997	1,609	Mod-Low	na	na	21	258	236
1998	1,970	Moderate	na	na	91	980	965
1999	2,649	Mod-High	na	na	106	2,282	2,282
2000	5,064	Mod-High	na	na	116	4,423	4,423
2001	4,315	Mod-Low	3,768	na	98	2,288	2,288
2002	3,990	High	na	na	125	3,223	3,223
2003	5,075	Moderate	na	na	83	2,342	2,342
Mean	**3,600**	**Moderate**	**na**	**na**	**82**	**2,028**	**2,024**

Lake Ozette sockeye exhibit a four-year brood cycle, and for this reason trends were evaluated in four brood-year groups (brood years [BY] A, B, C, and D). The mean run size over the last four years can be compared to the preceding four years. Between 1996 and 1999 the run size averaged 2,590 sockeye, while from 2000 to 2003 the run size averaged just over 4,600 sockeye. Within these two four-year cycles, the average return increased by approximately 78 percent between the first and second period. Much of the increased production is likely a result of increased adult returns from Umbrella Creek Hatchery releases, and increased natural production in Umbrella Creek. Nearly 210,000 BY 1996 fed fry and fingerlings were released into Umbrella Creek in 1997 and these releases composed a large portion of the BY 2000 run. Figure 2.12 depicts the estimated run sizes for 1996 through 2003 and compares the proportion of the run-size estimates that are based upon expansion, as well as the percentage (in days) of the run in which the weir was deployed.

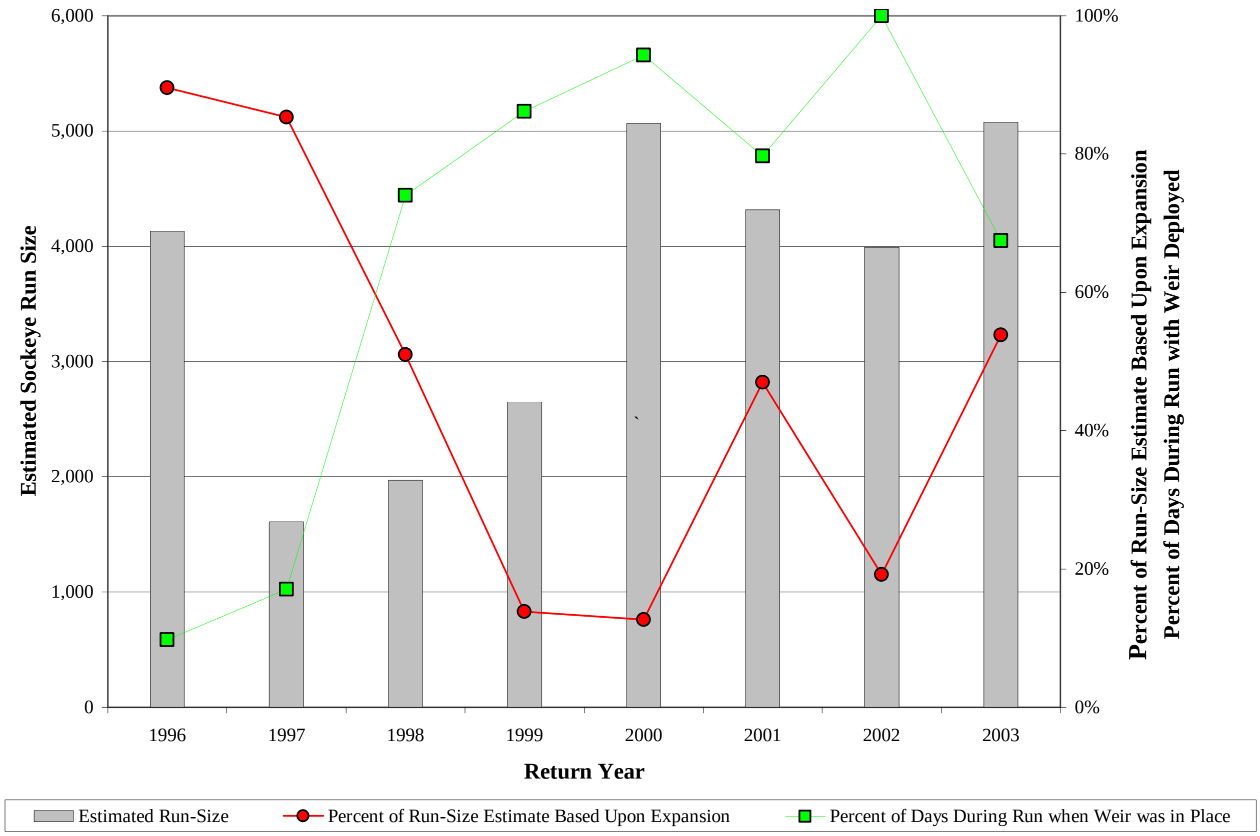

Figure 2.12. Estimated Lake Ozette sockeye run sizes for return years 1996 to 2003 contrasted with the proportion of the run-size estimates that were based upon expansion and the percentage of run-days in which the weir was deployed (source: Haggerty et al. 2007).

2.9 LAKE OZETTE SOCKEYE HATCHERY PRACTICES

In its 1996 status review, the BRT estimated that approximately 24 percent of the sockeye fry entering the lake rearing environment between 1988 and 1995 were of hatchery origin (Gustafson et al. 1997). The team expressed concern about the potential genetic effects of hatchery practices at that time, which included purposeful interbreeding of sockeye with genetically dissimilar kokanee salmon. These concerns were addressed in detail during the development of the Makah Tribe's Lake Ozette Sockeye Hatchery and Genetic Management Plan (HGMP) (MFM 2000).

The first sockeye releases into Lake Ozette were from out-of-basin broodstock sources. The last out-of-basin sockeye stocking in Lake Ozette occurred in 1983 (BY 1982 releases). All subsequent hatchery stocking efforts in the watershed relied only on sockeye salmon returning to the spawning grounds within the Lake Ozette watershed as the broodstock source. Adult returns resulting from past out-of-basin hatchery plants had the potential to interbreed with the native Lake Ozette sockeye, although the extent of non-native sockeye stocking was relatively low and its success was unknown. The first documented releases of non-native juvenile sockeye into Lake Ozette occurred with a brood year 1936 plant of approximately 450,000 sockeye fingerlings from the U.S. Bureau of Fisheries Birdsview Station at Baker Lake (Kemmerich 1945). Kemmerich (1945) states that additional transfers of sockeye juveniles from Quilcene and Quinault stations occurred after 1937, but the numbers and dates of those releases were not available. The only other documented out-of-basin sockeye releases were in 1983, when 120,000 (BY 1982) Lake Quinault sockeye fingerlings were released into Lake Ozette (MFM, unpublished hatchery out-planting records). In addition to non-native sockeye, releases of non-native kokanee into Lake Ozette have also been documented. In 1940, over 108,000 kokanee fry from the Lake Crescent Trout Hatchery were released into Lake Ozette (Kloempken 1996 *in* Gustafson et al. 1997). Dlugokenski et al. (1981) also reports a kokanee release of unknown quantity and origin into Lake Ozette in 1958.

2.9.1 Recent Sockeye Salmon Artificial Propagation Efforts (1984-1999)

Initially, hatchery operations and planning attempted to follow the recommendations set forth in Dlugokenski et al. (1981). Dlugokenski et al. developed three management alternatives for rebuilding Lake Ozette sockeye abundance: 1) no action; 2) rehabilitation of existing beach-spawning population and habitat; and 3) importation of an out-of-basin sockeye stock. They recommended management alternative 3 and suggested that 3-5 million sockeye eggs per year should be imported, hatched, and reared in Umbrella Creek over an 8-year period. They believed that use of tributaries for spawning would be required to increase the number of sockeye in Lake Ozette, and that the remaining beach-spawning sockeye aggregation could not adapt to the tributary spawning environment.

It was determined that a local stock with tributary spawners was needed. During the fall of 1982, the Lake Ozette Steering Committee met and decided that their efforts should focus on obtaining broodstock from Lake Quinault (MFM 1983b). The steering committee, WDFW, USFWS, and ONP all wrote letters of support declaring their preference for the Lake Quinault broodstock, in an attempt to secure eggs for hatching and rearing during the spring of 1983 (MFM 1983b). The low run size in 1983 prevented the Tribe from obtaining eggs from Lake Quinault. With a recently constructed incubation facility and no sockeye eggs, the effort to procure broodstock to supply eggs shifted to the Lake Ozette spawning beaches during the fall of 1983. Broodstock were collected from Olsen’s Beach and eggs fertilized from spawners were then incubated at the Umbrella Creek facility. Resultant fry were released into Umbrella Creek at the Hoko-Ozette Road Bridge. In the end, eggs from Lake Quinault were obtained for only one year (BY 1982) and in numbers well below the recommendations set forth by Dlugokenski et al. (1981). Efforts to obtain eggs from Lake Quinault slowly waned and attention focused on collecting native beach spawning sockeye from Lake Ozette as the primary broodstock source.

Broodstock were collected from Olsen’s Beach every year between 1983 and 1999, except for 1984 and 1989. Additional broodstock were collected from Allen’s Beach in

1987, 1988, 1991, 1992, 1994, 1995, and 1996, and from Umbrella Creek in 1997. It is not possible to quantify the number of broodstock collected from the two beach spawning aggregations for all years collections were made, but the vast majority of broodstock were collected from Olsen's Beach during this period. The number of fish collected and the resulting releases varied significantly between years. From 1986 to 1999, a total of 1,415 sockeye salmon were collected from the spawning beaches and used as broodstock. Table 2.4 illustrates the total number of fingerlings or fry and eggs produced from broodstock collected at Lake Ozette sockeye spawning beaches and released at various locations in the watershed from 1984 through 2000. Figure 2.13 depicts the number of fish or eggs released for each year during this period, for each release site.

Table 2.4. Total number of fingerlings or fry and eggs produced from broodstock collected at Lake Ozette sockeye spawning beaches, released at various locations in the watershed from 1984 through 2000 (modified from MFM 2000).

Release Site	**Number of Years**	**Total Number of Fry or Fingerlings Released**	**Total Number of Eggs Planted**	**Total Number of Released Fry and Eggs**
Umbrella Creek	8	691,748	0	691,748
Lake Ozette	8	242,599	16,628	259,227
Big River	1	0	14,299	14,299
Crooked Creek Mainstem	1	0	34,530	34,530
N.F. Crooked Creek	3	34,500	67,589	102,089
TOTAL		**968,847**	**133,046**	**1,101,893**

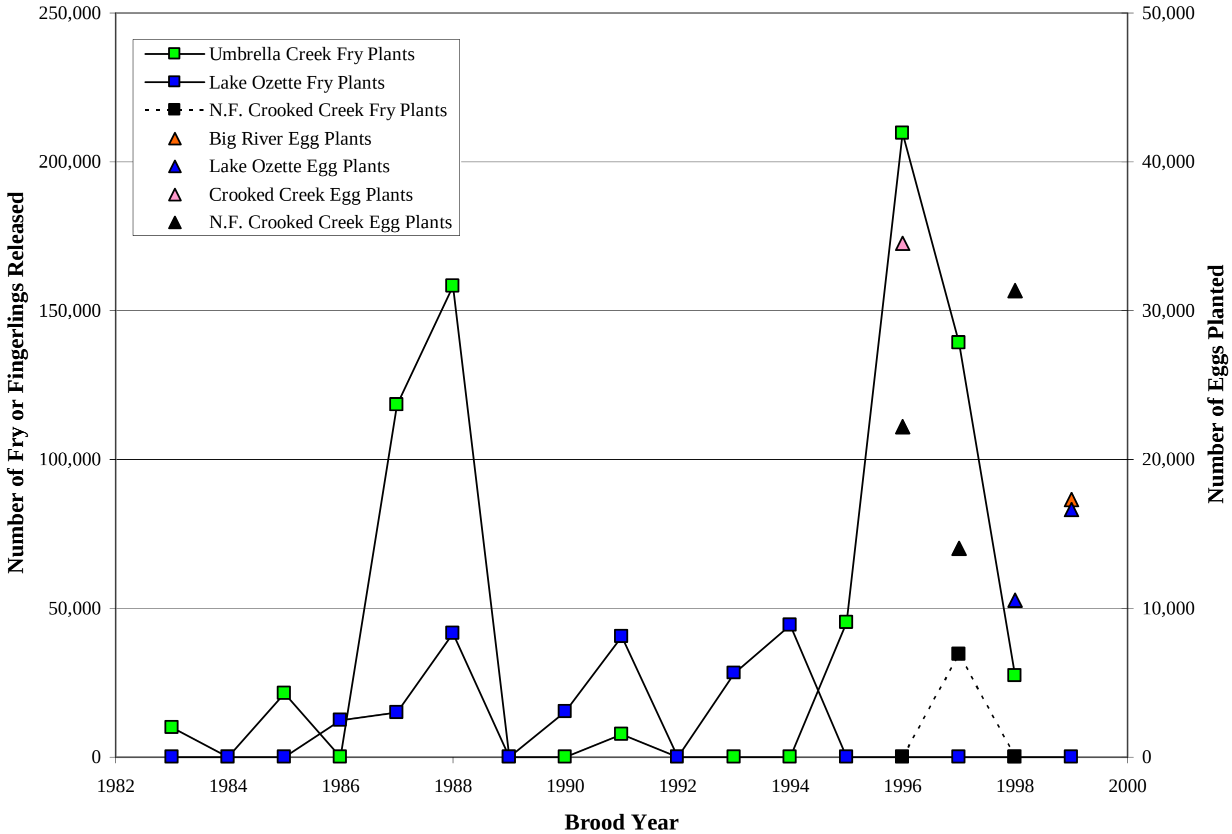

Figure 2.13. Total number of sockeye fry or fingerlings and eggs produced from broodstock collected at Lake Ozette beach spawning grounds released into various areas of the Lake Ozette watershed from 1984 through 2000 (BY 1983 to BY 1999; source: MFM, unpublished hatchery release data).

2.9.2 Hatchery and Genetic Management Plan

The ESA listing of Lake Ozette sockeye in 1999 necessitated the development of a Hatchery and Genetic Management Plan (HGMP) (MFM 2000) for the hatchery program to receive Federal authorization under the ESA. Actions that may affect listed species can be reviewed by NMFS through ESA section 7, section 10, or the 4(d) rule, and “take” prohibitions under section 9 of the ESA can be limited for actions considered sufficiently conservative (NMFS 2003). NMFS, with agreement from the Makah Tribe, evaluated the HGMP for effects on Lake Ozette sockeye under Limit 6 of the ESA 4(d) Rule for the listed ESU (65 FR 42422). The HGMP was evaluated under Limit 6 of the Rule because of its standing as a joint tribal/state resource management plan (RMP), reflecting the co-management status of the Makah Tribe and WDFW in managing the salmon resource. NMFS issued a final determination for the HGMP in July 2003, finding that the plan adequately addressed criteria under Limit 6 of the 4(d) rule, exempting the plan from the

ESA section 9 take prohibitions (69 FR 18874). The joint RMP evaluated by NMFS is the HGMP and will be referred to in this document as the HGMP.

The HGMP is part of the overall recovery planning process for Lake Ozette sockeye. It contains a complex set of goals and a well-defined strategy for assisting recovery and preserving the genetic diversity of Lake Ozette sockeye. The HGMP contains measures and actions exclusively needed to maintain the operation of the hatchery component of Lake Ozette sockeye recovery, as well as population and habitat monitoring components not normally associated with hatchery activities. The HGMP clearly states that the HGMP alone will not result in recovery of Lake Ozette sockeye, and that a comprehensive approach to habitat protection, habitat assessment, and habitat protection and restoration is needed so that hatchery and habitat components can work in concert with one another to promote species recovery.

The HGMP includes an extensive monitoring plan that allows for many of the program performance indicators to be monitored and evaluated annually. Much of the new population status, life history, ecological interaction, and habitat limiting factors data presented in this recovery plan and the LFA were collected as part of the HGMP monitoring effort. Monitoring and annual program evaluation also make it possible to adjust hatchery and research actions consistent with the adaptive management approach specified in the HGMP.

The HGMP lists these goals:

1. Prevent further decline of the ESU population.
2. Increase abundance of naturally spawning Lake Ozette sockeye salmon to self-sustaining levels that meet future estimated escapement goals and enable sustainable tribal and non-tribal commercial, ceremonial and subsistence (C&S), and sport fisheries.
3. Conserve the genetic and ecological characteristics of Lake Ozette sockeye salmon.
4. Increase distribution and diversity of Lake Ozette sockeye salmon in their present and historical localities along the lakeshore of Lake Ozette and its tributaries using supplementation, reintroduction, and natural colonization.
5. Rebuild naturally spawning aggregations of sockeye in the Ozette watershed sufficiently to restore their role in ecological processes, including nutrient recycling and serving as prey for other species of fish and wildlife, and sufficiently to restore traditional native uses (MFM 2000).

The HGMP incorporates an innovative approach to adaptive management, treating restoration activities as experiments that will produce knowledge needed to refine future actions, including those necessary to help meet recovery goals included in this plan. It contains four steps:

1. Identify recovery strategies that test hypotheses about the limiting factors or causes for decline of the population.

2. Design recovery activities as experiments to collect information from which decision-makers can learn.
3. Analyze the responses to recovery activities.
4. Implement changes based on synthesis of information and adaptive management.

The initial strategy of the HGMP included two main components:

1. Reintroduction and supplementation efforts were directed to Big River and Umbrella Creek, using tributary returns for broodstock, with intensive monitoring of the experimental introductions to clearly understand their outcome. The intent is that reintroduction into these tributaries will increase viability (abundance, productivity, spatial structure, and diversity) of Lake Ozette sockeye, which should be of long-term benefit to the recovery of the population.
2. Artificial production activities for beach spawning fish were limited to studies of limiting factors, genetic composition, and life history, using methods described in the HGMP. Determinations of whether and how to supplement or reintroduce lake aggregations will be made pending results of the research.

Implementation of the HGMP started with BY 2000 returns to the lake. Since then, no broodstock have been collected from the beaches and no planting in the Crooked Creek watershed has occurred. Hatchery efforts have focused on refining broodstock capture, incubation, and release methods within Umbrella Creek; refining incubation and release strategies within Big River; and conducting small-scale limiting factor studies at the spawning beaches.

Since the implementation of the HGMP began in BY 2000, a total of 746 sockeye (379 females and 367 males) have been collected for broodstock from Umbrella Creek (less than 10 percent of the total adult return to Umbrella Creek between 2000 and 2003; MFM unpublished broodstock collection data). A total of 783,617 fry and fingerlings have been released into the Umbrella Creek (36 percent of the total) and Big River (64 percent) watersheds (MFM unpublished sockeye release data). A simplified summary of juvenile sockeye hatchery releases in the Lake Ozette watershed is presented in Table 2.5.

Table 2.5. Summary of HGMP sockeye fry and fingerling releases in the Ozette watershed for brood years 2000 through 2003 (source: MFM, unpublished hatchery release data).

Brood Year	Release Date	Size (Grams)	Number of Fry or Fingerlings Released	Release Site	Broodstock Source
2000	April/May 2001	0.13	63,201	Big River (Stony Creek)	Umbrella Creek
2000	7/29/2001	1.01	50,168	Big River (Stony Creek)	Umbrella Creek
2000	7/27/2001	1.17	48,379	Umbrella Creek	Umbrella Creek
2000	7/27/2001	0.8	32,328	Umbrella Creek	Umbrella Creek
2001	April/May 2002	0.13	75,900	Big River (Stony Creek)	Umbrella Creek
2001	6/28/2002	0.86	75,352	Big River (Stony Creek)	Umbrella Creek
2001	July 2002	1.0-1.57	94,958	Umbrella Creek	Umbrella Creek
2002	6/5/2003	0.32	74,377	Big River (Stony Creek)	Umbrella Creek
2002	6/5/2003	0.91	47,990	Big River (Stony Creek)	Umbrella Creek
2002	6/26/2003	0.74	79,325	Umbrella Creek	Umbrella Creek
2002	June 2003	0.4	24,568	Umbrella Creek	Umbrella Creek
2003	May 2004	0.16	102,779	Big River (Stony Creek)	Umbrella Creek
2003	7/2/2004	0.6	12,792	Big River (Stony Creek)	Umbrella Creek
2003	5/25/2004	0.57	1,500	Umbrella Creek	Umbrella Creek

The HGMP limits the tributary reintroduction program to 12 years, or three sockeye salmon generations, per release site. After 12 years (in 2012), the program will be evaluated. If it has been successful in establishing self-sustaining sockeye runs that meet escapement goals, it will be terminated. In its final determination on the HGMP, NMFS further stated that “If, after 12 years, the program is meeting performance standards and is expected to achieve, but has not yet fully accomplished, program goals, continuation of specific components of the program will be proposed and evaluated” (NMFS 2003).

NMFS conducted an assessment of the Lake Ozette hatchery program’s relative contribution to the conservation of the listed species (NMFS 2004). This assessment included a detailed evaluation of the hatchery program’s effects on ESU viability, including the parameters of abundance, productivity, spatial structure, and diversity. NMFS concluded that the hatchery program is increasing the abundance of naturally spawning sockeye in the ESU; however, tributary spawners from the program are isolated (by design) from the beach spawning aggregations, and are therefore unlikely to benefit either the abundance or the productivity of the natural-origin beach-spawners.

Similarly, NMFS concluded that the hatchery program is likely to increase the spatial structure of the ESU as a whole, although it is not likely to increase the spatial structure of the beach-spawning aggregations. The program is expected to affect the ESU’s diversity by extending the range of spatial distribution, which may, in turn, contribute to life history diversity and increase the resiliency of the population (NMFS 2004).